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EDITED BY

HOWARD J. ROGERS, A.M., LL.D.

DIRECTOR OF CONGRESSES

VOLUME VI

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DIVISION E — UTILITARIAN SCIENCES

DIVISION E — UTILITARIAN SCIENCES

(*Hall* 1, *September* 20, 10 *a. m.*)

SPEAKER: PRESIDENT DAVID STARR JORDAN, Leland Stanford, Jr., University.

UTILITARIAN SCIENCE

BY DAVID STARR JORDAN

[**David Starr Jordan**, President of Leland Stanford, Jr., University since 1891. b. January 19, 1851, Gainesville, Wyoming County, New York. M.S. Cornell, 1872; LL.D. *ibid.* 1886; Ph.D. Butler University, 1880; M.D. University of Indiana, 1875; Post-Graduate, Harvard University, London, Paris. Professor of Biology, Butler University, 1875–79; Professor of Zoölogy, University of Indiana, 1879–85; President of Indiana University, 1885–91; Associate of the U. S. Fish Commission since 1878; Head of Bering Sea Commission, 1896–98; President of California Academy of Sciences; Fellow of A. O. U.; Member of American Philosophical Society, etc. **Author of** many books, including *Fishes of Northern and Middle America; Science Sketches; Manual of the Vertebrates; Guide to Study of Fishes; The Innumerable Company, Care and Culture of Men; The Voice of the Scholar*, etc.]

IT falls to my lot to-day, to discuss very briefly, in accordance with the Programme of this Congress, some of the common features of utilitarian science, with a word as to present and future lines of investigation or instruction in some of those branches of the applications of knowledge which have been assigned to the present division.

Applied science cannot be separated from pure science; for pure science may develop at any quarter the greatest and most unexpected economic values; while on the other hand, the application of knowledge must await the acquisition of knowledge before any high achievement can be reached. For these reasons, the classification adopted in the present Congress, or any other classification of sciences into utilitarian science and other forms of science, must be incomplete and even misleading. Whatever is true is likely some time to prove useful, and all error is likely to prove some time disastrous. From the point of view of the development of the human mind, all truth is alike useful, and all error is alike mischievous.

In point of development, pure science must precede utilitarian science. Historically, this seems to be not true; for the beginnings of science in general, as alchemy, astrology, and therapeutics, seem to have their origin in the desire for the practical results of knowledge. Men wanted to acquire gold, to save life, to forecast the future, not for knowledge's sake, but for the immediate results of success in these directions. But even here accurate knowledge must precede any success in its application, and accuracy of knowledge is all that we mean by pure science. Moreover, as through the ages the representatives of the philosophies of the day, the *a priori* explanations of the universe, were bitterly and personally hostile to all inductive conclusions based on the study of base matter, men of science were forced to disguise their work under a utilitarian cloak. This is more or less true even to this day, and the greatest need of utilitarian science is still, as a thousand years ago, that this cloak should be thrown off, and that a larger and stronger body of workers in pure science should be developed to give the advance in real knowledge on which the thousands of ingenious and noble applications to utilitarian ends must constantly depend.

It is a fundamental law of psychology that thought tends to pass over into action. Applied science is knowledge in action. It is the flower of that highest philanthropy of the ages by which not even thought exists for itself alone, but must find its end in the enlargement of human control over matter and force or the amelioration of the conditions of human life.

The development of all science has been a constant struggle, a struggle of fact against philosophy, of instant impressions against traditional interpretations, of truth against "make-believe." For men are prone to trust a theory rather than a fact; a fact is a single point of contact; a theory is a circle made of an infinite number of points, none of them, however, it may be, real points of contact.

The history of the progress of science is written in human psychology rather than in human records. It is the struggle of the few realities or present sense-impressions against the multitude of past impressions, suggestions, and explanations. I have elsewhere said that the one great discovery of the nineteenth century — forestalled many ages before — was that of the reality of external things. Men have learned to trust a present fact or group of facts, however contradictory its teachings, as opposed to tradition and philosophy. From this trust in the reality of the environment of matter and force, whatever these may be, the great fabric of modern science has been built up. Science is human experience of contact with environment tested, set in order, and expressed in terms of other human experience. Utilitarian science is that part of all this knowledge which we can use in our lives, in our business. What is pure science to one is applied science to another. The investigation of the laws of heredity may be strictly academic to us of the university, but they are utilitarian as related to the preservation of the nation or to the breeding of pigs. In the warfare of science the real in act and motive has been persistently substituted for the unreal. Men have slowly learned that the true glory of life lies in its wise conduct, in the daily act of love and helpfulness, not in the vagaries fostered by the priest or in the spasms of madness which are the culmination of war. To live here and now as a man should live constitutes the ethics of science, and this ideal has been in constant antithesis to the ethics of ecclesiasticism, of asceticism, and of militarism.

The physical history of the progress of science has been a struggle of thinkers, observers, and experimenters against the dominant forces of society. It has been a continuous battle, in which the weaker side, in the long run, is winner, having the strength of the earth behind. It has been incidentally a conflict of earth-born knowledge with opinions of men sanctioned by religion; of present fact with preëstablished system, visibly a warfare between inductive thought and dogmatic theology.

The real struggle, as already indicated, lies deeper than this. It is the effort of the human mind to relate itself to realities in the midst of traditions and superstitions, to realize that nature never contradicts herself, is always complex, but never mysterious. As a final result all past systems of philosophy, perhaps all possible systems, have been thrown back into the realm of literature, of poetry, no longer controlling the life of action, which rests on fact.

This conflict of tendencies in the individual has become a conflict among individuals as each is governed by a dominant impulse. The cause of tradition becomes that of theology; — for men have always claimed a religious sanction for their own individual bit of cosmic philosophy. Just as each man in his secret heart, the centre of his own universe, feels himself in some degree the subject of the favor of the mysterious unseen powers, so does society in all ages find a mystic or divine warrant for its own attitude towards life and action, whatever that may be.

The nervous system of man, inherited from that of the lower animals, may be regarded as primarily a means of making locomotion safe. The reflex action of the nerve centre is the type of all mental processes. The sensorium, or central ganglion, receives impressions from the external world representing, in a way, various phases of reality. The brain has no source of knowledge other than sensation. All human knowledge comes through human experience. The brain, sitting in darkness, has the primary function of converting sensory impressions into impulses to action. To this end the motor nerves carry impulses outward to the muscles. The higher function of nerve-action, which we call the intellect, as distinguished from simple reflex action and from instinct, is the choice among different responses to the stimulus of external realities. As conditions of life become more complex, the demands of external realities become more exacting. It is the function of the intellect to consider and of the mind to choose. The development of the mind causes and permits complexity in external relations. Safety in life depends on choosing the right response to external stimulus. Wrong choice leads to failure or to death.

From the demands of natural selection results the intense practicality of the mental processes. Our senses tell us the truth as to external nature, in so far as such phases of reality have been essential to the life of our ancestors. To a degree, they must have seen "things as they really are," else they should not have lived to continue the generation. Our own individual ancestors through all the ages have been creatures of adequate accuracy of sensation and of adequate power of thought. Were it not so they could not have coped with their environment. The sensations which their brains translated into action contained enough of absolute reality to make action safe. That our own ordinary sensations and our own inductions from them are truthful in their essentials, is proved by the fact that we have thus far safely trusted them. Science differs from common sense mainly in the perfection of its tools. That the instruments of precision used in science give us further phases of reality is shown by the fact that we can trust our lives to them. We find it safer to do so than to trust our unaided senses.

While our senses tell us the truth as to familiar things, as rocks and trees, foods and shelter, friends and enemies, they do not tell us the whole truth: they go only so far as the demands of ancestral environment have forced them to go. Chemical composition our senses do not show. Objects too small to handle are too small to be seen. Bodies too distant to be reached are never correctly apprehended. Accuracy of sense decreases as the square of the distance increases. Sun and stars, clouds and sky, are in fact very different from what they seem to the senses.

In matters not vital to action, exactness of knowledge loses its importance. Any kind of belief may be safe, if it is not to be carried over into action. It is perfectly safe, in the ordinary affairs of life, for one who does not propose to act on his convictions to believe in witches and lucky stones, imps and elves, astral bodies and odic forces. It is quite as consistent with ordinary living to accept these as objective realities as it is to have the vague faith in microbes and molecules, mahatmas and protoplasm, protective tariffs and manifest destiny, which forms part of the mental outfit of the average American citizen to-day. Unless these conceptions are to be brought into terms of personal experience, unless in some degree we are to trust our lives to them, unless they are to be wrought into action, they are irrelevant to the conduct of life. As they are tested by action, the truth is separated from the falsehood, and the error involved in vague or silly ideas becomes manifest. As one comes to handle microbes, they become as real as bullets or oranges and as susceptible of being manipulated. But the astral body covers only ignorance and ghosts vanish before the electric light.

Memory-pictures likewise arise to produce confusion in the mind. The record of past realities blends readily with the present. Men are gregarious creatures and their speech gives them the power to add to their own individual experiences the concepts and experiences of others. Suggestion and conventionality play a large part in the mental equipment of the individual man.

About the sense-impressions formed in his own brain each man builds up his own subjective universe. Each accretion of knowledge must be cast more or less directly in terms of previous experience. By processes of suggestion and conventionality the ideas of the individual become assimilated to those of the multitude. Thus myths arise to account for phenomena not clearly within the ordinary experiences of life. And in all mythology the unknown is ascribed not to natural forces, but to the action of the powers that transcend nature, that lie outside the domain of the familiar and the real.

It has been plain to man in all ages that he is surrounded by forces stronger than himself, invisible and intangible, inscrutable in their real nature, but terribly potent to produce results. He cannot easily trace cause and effect in dealing with these forces; hence it is natural that he should doubt the existence of relations of cause and effect. As the human will seems capricious because the springs of volition are hidden from observation, so to the unknown will that limits our own we ascribe an infinite caprice. All races of men capable of abstract thought have believed in the existence of something outside themselves whose power is without human limitations. Through the imagination of poets the forces of nature become personified. The existence of power demands corresponding will. The power is infinitely greater than ours; the sources of its action inscrutable: hence man has conceived the unknown first cause as an infinite and unconditioned man. Anthropomorphism in some degree is inevitable, because each man must think in terms of his own experience. Into his own personal universe, all that he knows must come.

Recognition of the hidden but gigantic forces in nature leads men to fear and to worship them. To think of them either in fear or in worship is to give them human forms.

The social instincts of man tend to crystallize in institutions even his common hopes and fears. An institution implies a division of labor. Hence, in each age and in each race men have been set apart as representatives of these hidden forces and devoted to their propitiation. These men are commissioned to speak in the name of each god that the people worship or each demon the people dread.

The existence of each cult of priests is bound up in the perpetuations of the mysteries and traditions assigned to their care. These traditions are linked with other traditions and with other mystic explanations of uncomprehended phenomena. While human theories of the sun, the stars, the clouds, of earthquakes, storms, comets, and disease, have no direct relation to the feeling of worship, they cannot be disentangled from it. The uncomprehended, the unfamiliar, and the supernatural are one and the same in the untrained human mind; and one set of prejudices cannot be dissociated from the others.

To the ideas acquired in youth we attach a sort of sacredness. To the course of action we follow we are prone to claim some kind of mystic sanction; and this mystic sanction applies not only to acts of virtue and devotion, but to the most unimportant rites and ceremonies; and in these we resent changes with the full force of such conservatism as we possess.

It is against limited and preconceived notions that the warfare of science has been directed. It is the struggle for the realities on the part of the individual man. Ignorance, prejudice, and intolerance, in the long run, are one and the same thing. In some one line, at least, every lofty mind throughout the ages has demanded objective reality. This struggle has been one between science and theology only because theological misconceptions were entangled with crude notions of other sorts. In the experience of a single human life there is little to correct even the crudest of theological conceptions. From the supposed greater importance of religious opinions in determining the fate of men and nations, theological ideas have dominated all others throughout the ages; and in the nature of things, the great religious bodies have formed the stronghold of conservatism against which the separated bands of science have hurled themselves, seemingly in vain.

But the real essence of conservatism lies not in theology. The whole conflict, as I have already said, is a struggle in the mind of man. From some phase of the warfare of science no individual is exempt. It exists in human psychology before it is wrought in human history. There is no better antidote to bigotry than the study of the growth of knowledge. There is no chapter in history more encouraging than that which treats of the growth of open-mindedness. The study of this history leads religious men to avoid intolerance in the present, through a knowledge of the evils intolerance has wrought in the past. Men of science are spurred to more earnest work by the record that through the ages objective truth has been the final test of all theories and conceptions. All men will work more sanely and more effectively as they realize that no good to religion or science comes from " wishing to please God with a lie."

It is the mission of science to disclose — so far as it goes — the real nature of the universe. Its function is to eliminate, wherever it be found, the human equation. By methods of precision of thought and instruments of precision of observation and experiment, science seeks to make our knowledge of the small, the distant, the invisible, the mysterious, as accurate, as practical, as our knowledge of common things. Moreover, it seeks to make our knowledge of common things accurate and precise, that this accuracy and precision may be translated into action. For the ultimate end of science as well as its initial impulse is the regulation of human conduct. Seeing true means thinking right. Right thinking means right action. Greater precision in action makes higher civilization possible. Lack of precision in action is the great cause of human misery; for misery is the inevitable result of wrong conduct. "Still men and nations reap as they have strewn."

A classic thought in the history of applied science is expressed in these words of Huxley: "There can be no alleviation of the sufferings of man except in absolute veracity of thought and action and a resolute facing of the world as it is." "The world as it is" is the province of science. "The God of the things as they are is the God of the highest heaven." And as to the sane man, the world as it is is glorious, beautiful, harmonious, and divine, so will science, our tested and ordered knowledge of it, be the inspiration of art, poetry, and religion.

Pure science and utilitarian science merge into each other at every point. They are one and the same thing. Every new truth can be used to enlarge human power or to alleviate human suffering. There is no fact so remote as to have no possible bearing on human utility. Every new conception falls into the grasp of that higher philanthropy which rests on the comprehension of the truths of science. For science is the flower of human altruism. No worker in science can stand alone. None counts for much who tries to do so. He must enter into the work of others. He must fit his thought to theirs. He must stand on the shoulders of the past, and must crave the help of the future. The past has granted its assistance to the fullest degree of the most perfect altruism. The future will not refuse; and, in return, whatever knowledge it can take for human uses, it will choose in untrammeled freedom. The sole line which sets off utilitarian science lies in the limitation of human strength and of human life. The single life must be given to a narrow field, to a single strand of truth, following it wherever it may lead. Some must teach, some must investigate, some must adapt to human uses. It is not often that these functions can be united in the same individual. It is not necessary that they should be united; for art is long, though life is short, and for the next thousand years science will be still in its infancy. We stand on the threshold of a new century; a century of science; a century whose discoveries of reality shall far outweigh those of all centuries which have preceded it; a century whose glories even the most conservative of scientific men dare not try to forecast. And this twentieth century is but one — the least, most likely — of the many centuries crowding to take their place in the line of human development. In each century we shall see a great widening of the horizon of human thought, a great increase of precision in each branch of human knowledge, a great improvement in the conditions of human life, as enlightenment and precision come to be controlling factors in human action.

In the remaining part of this address I shall discuss very briefly some salient features of practice, investigation, and instruction in those sciences which in the scheme of classification of this Congress have been assigned to this division. In this discussion I have received the invaluable aid of a large number of my colleagues in scientific work, and from their letters of kindly interest I have felt free to make some very interesting quotations. To all these gentlemen (a list too long to be given here) from whom I have received aid of this kind, I offer a most grateful acknowledgment.

Engineering

The development of the profession of engineering in America has been the most remarkable feature of our recent industrial as well as educational progress. In this branch of applied science our country has come to the very front, and this in a relatively short time. To this progress a number of distinct forces have contributed. One lies in the temperament of our people, their native force, and their tendency to apply knowledge to action. In practical life the American makes the most of all he knows. Favoring this is the absence of caste feeling. There is no prejudice in favor of the idle man. Only idlers take the members of the leisure class seriously. There is, again, no social discrimination against the engineer as compared with other learned professions. The best of our students become working engineers without loss of social prestige of any sort. Another reason is found in the great variety of industrial openings in America, and still another in the sudden growth of American colleges into universities, and universities in which both pure and applied sciences find a generous welcome. For this the Morrill Act, under which each state has developed a technical school, under federal aid, is largely responsible. In the change from the small college of thirty years ago, a weak copy of English models, to the American university of to-day, many elements have contributed. Among these is the current of enlightenment from Germany, and at the same time the influence of far-seeing leaders in education. Notable among these have been Tappan, Eliot, Agassiz, and White. To widen the range of university instruction so as to meet all the intellectual, esthetic, and industrial needs of the ablest men is the work of the modern university. To do this work is to give a great impetus to pure and to applied science.

Two classes of men come to the front in the development of engineering: the one, men of deep scientific knowledge, to whom advance of knowledge is due, the other the great constructive engineers; men who can work in the large and can manage great enterprises with scientific accuracy and practical success. Everywhere the tendency in training is away from mere craftsmanship and towards power of administration. The demands of the laboratory leave less and less time for the shop. "Two classes of students," says a correspondent, "should be encouraged in our universities: First, the man whose scientific attainments are such that he will be able to develop new and important processes, the details of which may be directly applied. This type of man is the scientific engineer. The other is the so-called practical man, who will not only actually carry on engineering work, but may be called on to manage large enterprises. If his temperament and ability are such as to give him a thorough command of business methods and details, while he is in addition a good engineer, he will find a field of great usefulness before him on leaving the university. The university should encourage young men to undertake the general executive work necessary to handling men and in the many details of large enterprises. The successful man of this character is necessarily a leader, and the university should recognize that such a man can be of great influence in the world, if he is thoroughly and broadly educated."

"We need," says another correspondent, "men possessing a better general training than most of those now entering and leaving our engineering schools. We need more thoroughly trained teachers of engineering, men who combine theoretical training with a wide and constantly increasing experience, men who can handle the factors of theory, practice, and economics."

"Technical education," says another correspondent, "should look beyond the individual to the aggregate, and should aim to shape its activities so as to develop at the maximum number of points sympathetic and helpful relations with the industrial and engineering interests of the state. This means careful and steady effort towards the coördination of the activities of the technical school with the general condition of industry and engineering as regards its raw materials, its constructive and productive operations, its needs and demands with regard to personnel, and its actual or potential trend of progress."

The coming era in engineering is less a period of discovery and invention than of application on a large scale of principles already known. Greater enterprises, higher potentialities, freer use of forces of nature, all these are in the line of engineering progress.

"The realm of physical science," says a correspondent, "has become to the practical man a highly improved agricultural land, whereas in earlier days it was a virgin country possessing great possibilities and exacting but little in the way of economic treatment."

In all forms of engineering, practice is changing from day to day; the principles remain fixed. In electricity, for example, the field of knowledge "extends far beyond the direct limits or needs of electrical engineers."

"The best criticism as to engineering education came formerly almost entirely from professors of science and engineering. To-day the greatest and most wholesome source of such criticism comes from those engaged in practical affairs. We have begun a régime wherein coördinated theory and practice will enter into the engineering training of young men to a far greater and more profitable extent than ever before."

"The marvelous results in the industrial world of to-day," says a correspondent, "are due largely to the spirit of 'usefulness, activity, and coöperation' that exists in each community of interests and which actuates men employing the means which applied science has so bountifully accorded. I know of no greater need of engineering education in our country to-day than that its conduct in each institution should be characterized by the same spirit of usefulness, activity, and coöperation."

In mining, as in other departments of engineering, we find in the schools the same growing appreciation of the value of training at once broad, thorough, and practical, and the same preference for the university-trained engineer over the untrained craftsman.

The head of a great mining firm in London writes me that "for our business, what we desire are young men of good natural qualifications, thoroughly trained theoretically without any so-called practical knowledge unless this knowledge has been gained by employment in actual works."

On the pay-roll of this English firm I find that five men receive salaries of more than $20,000. All these are graduates of technical departments of American universities. Seventeen receive from $6000 to $20,000. Nine of these were trained in American universities, one in Australia, and two in England, while five have risen from the ranks.

In the lower positions, most have been trained in Australia, a few in England, while in positions bearing a salary of less than $2500 most have risen from the ranks.

"Given men of equal qualifications," says the director of this firm, "the man of technical training is bound to rise to the higher position because of his greater value to his employer. As a rule, also, men who have been technically trained are, by virtue of their education, men who are endowed with a professional feeling which does not to the same extent exist among those men who have risen from the rank and file. They are therefore more trustworthy, and especially in mining work, where premium for dishonesty exists, for this qualification alone they are bound to have precedence. We do not by any means wish to disparage the qualifications of many men who have risen from the ranks to eminent positions, but our opinion may be concentrated in the statement that even these men would be better men had they received a thorough technical training."

The progress of chemical engineering is parallel with that in other departments of technology. Yet the appreciation of the value of theoretical training is somewhat less marked, and in this regard our manufacturers seem distinctly behind those of Germany.

"The development of chemical industries in the past history of the United States," says a correspondent, "was seriously delayed by the usually superficial and narrow training of the chemist in the colleges. Thus managers and proprietors came to undervalue the importance of chemical knowledge. The greatest need at present in the development of chemical industries is an adequate supply of chemists of thorough training to teach manufacturers the importance in their business of adequate chemical knowledge. Epoch-making advances in chemical industry will spring from the brain of great chemists, and to insure the production of a few of these, the country must expect to seed lavishly and to fertilize generously the soil from which they spring. Germany has learned the lesson well: other nations cannot long delay."

Agriculture

In the vast range of the applications of science to agriculture, the same general statements hold good. There is, however, no such general appreciation of the value of training as appears in relation to the various branches of training, and the men of scientific education are mostly absorbed in the many ramifications of the Department of Agriculture and in the state agricultural colleges and experiment stations. There are few illustrations of the power of national coöperation more striking than those shown in the achievements of the Department of Agriculture. I have no time to touch on the varied branches of agricultural research, the study of the chemistry of foods and soils, the practice of irrigation, the fight against adulterations, the fight against noxious insects, and all the other channels of agricultural art and practice. I can only commend the skill and the zeal with which all these lines of effort have been followed.

The art of agriculture is the application of all the sciences. Yet "agricultural education," writes a correspondent, "has not yet reached the dignity of other forms of technical education."

"The endowment of the science of agricultural research in the United States is greater than in any other country. The chief fault to be found is in striving too rapidly for practical applications and in not giving time enough for the fundamental research on which these applications must rest. The proportion of applied agricultural science in agriculture is too great in this country. While we do not need fewer workers in applied agricultural science, we do need more workers who would devote themselves to fundamental research."

Two branches of applied science not specifically noticed in our scheme of classification seem to me to demand a word of notice. One is selective breeding of plants and animals; the other, the artificial hatching of fishes. By the crossing of animals or plants not closely related, a great range of variety appears in the progeny. Some of these may have one or more of the desirable qualities of either parent. By selection of those possessing such qualities a new race may be formed in a few generations. The practical value of the results of such experiments cannot be over-estimated. Although by no means a modern process, the art of selective breeding is still in its infancy. Its practice promises to take a leading place among the economically valuable applications of science. At the same time, the formation of species of organisms under the hand of man throws constant floods of light on the great questions of heredity, variation, and selection in nature, the problem of the origin of species.

In this connection I may refer to artificial hatching and acclimatization of fishes, the work of the United States Bureau of Fisheries and of the fish commissions of the different states. There are many species of fish, notably those of the salmon family, in which the eggs can be taken and fertilized by artificial processes. These eggs can be hatched in protected waters so that the young will escape many of the vicissitudes of the brook and river, and a thousand young fishes can be sent forth where only a dozen grew before.

Medicine

In the vast field of medicine I can only indicate in a few words certain salient features of medical research, of medical practice, and of medical instruction in America.

In matters of research, the most fruitful line of investigation has been along the line of the mechanism of immunity from contagious diseases. To know the nature of microörganisms and their effect on the tissues is to furnish the means of fighting them. "The first place in experimental medicine to-day," says Dr. W. H. Welch, "is occupied by the problem of immunity." That medicine is becoming a scientific profession and not a trade is the basis of the growing interest of our physicians in scientific problems, and this again leads to increased success in dealing with matters of health and disease. The discovery of the part played by mosquitoes in the dissemination of malaria, yellow fever, dengue, elephantiasis, and other diseases caused by microörganisms marks an epoch in the study of these diseases. The conquest of diphtheria is another of the features of advance in modern medicine, and another is shown in the great development of surgical skill characteristic of American medical science. But the discoveries of the last decades have been rarely startling or epoch-making. They have rather tended to fill the gaps in our knowledge, and there remain many more gaps to fill, before medical practice can reach the highest point of adequacy. The great need of the profession is still in the direction of research, and research of the character which takes the whole life and energy of the ablest men demands money for its maintenance. We need no more medical colleges for the teaching of the elements. We need schools or laboratories of research for the training of the masters.

In the development of medicine there has been a steady movement away from universal systems and *a priori* principles, on the one hand, and, on the other hand, from blind empiricism, with the giving of drugs with sole reference to their apparent results. The applications of sciences — all sciences which deal with life, with force, and with chemical composition — must enter into the basis of medicine. Hence the insistent demand for better preliminary training before entering on the study of medicine. "Only the genius of the first order," says a correspondent, "can get on without proper schooling in his youth. What our medical investigators in this country most need is a thorough grounding in the sciences, especially physics and chemistry."

The instruction in medicine, a few years ago almost a farce in America, has steadily grown more serious. Laboratory work and clinical experience have taken the place of lectures, the courses have been lengthened, higher preparation for entrance has been exacted, though in almost all our schools these requirements are still far too low, and a more active and original type of teacher has been in demand. Even yet, so far as medical instruction is concerned, the hopeful sign is to be found in progress rather than in achievement. A college course, having as its major subjects the sciences fundamental to medicine, is not too much to exact of a student who aspires to be a physician worthy of our times and of the degree of our universities. First-hand knowledge of real things should be the keynote of all scientific instruction. "Far more effort is now made," writes a correspondent, "in both the preparatory and the clinical branches to give the student a first-hand knowledge of his subject. This tendency has still a long way to travel before it is in danger of being overdone. The practical result of this tendency is that the cost of education per student is greatly increased and the profits of purely commercial schools are thereby threatened. This forms, doubtless, the main source of the objection made by the weaker and less worthy schools to better methods of instruction. We need well-endowed schools of medicine that may carry on their work unhampered by the necessities of a commercial venture. Medical schools now exist in great numbers, — many of them cannot keep up with modern requirements, and necessarily their salvation lies in antagonizing everything in the nature of more ample and more expensive training."

Another correspondent writes, emphasizing the value of biologic studies: "The final comprehension of bodily activity in health and disease depends on knowledge of living things from ovum to birth, from birth to maturity, and from maturity to old age and death. Anything less than such fundamental knowledge requires constant guessing to fill up the gaps, and guesses are nearly always wrong."

In many regards, even our best schools of medicine seem to show serious deficiencies. The teaching of anatomy is still one of the most costly, as well as least satisfactory, of our lines of work. A correspondent calls attention to the fact that in making anatomy "practical" in our medical schools, " we expended last year $750,000 in the United States, twice the amount expended in Germany, with as a result neither practical anatomy nor scientific achievement." "Anatomy," he continues, "should be made distinctly a university department, on a basis similar to that of physics and chemistry. Unfortunately, university presidents still stand much in the way of the development of anatomy, for many of them seem to think that almost any one who wears the gown is good enough to become a professor of anatomy. Repeatedly have I witnessed the appointment of a know-nothing when a recognized young man might have been had for half the money." Our forces are dissipated, the fear of things scientific has destroyed even the practical in this noble old mother science which is still giving birth to new sciences and to brilliant discoveries.

Among other matters too much neglected are personal hygiene, a matter to which the physician of the past has been notoriously and joyously indifferent. Especially is this true as regards the hygiene of exercise and the misuse of nerve-affecting drugs.

Public sanitation as well deserves more attention. "The demand for adequately trained officers of public health is not what it should be, and our public service as a whole is far below that of European countries. Both public opinion and university authorities are responsible for this condition."

The hygiene of childhood, in which line great advances are made, is still not adequately represented in most of our medical colleges, and the study of psychiatry and nervous disturbances in general is not sufficiently lifted from the realm of quackery. "Not only," says a correspondent, "should psychiatry be taught in every medical school, but it should be taught from a clinical standpoint. Every city in which there are medical schools should have a psychopathic hospital for the reception of all cases of alleged insanity and for their study, treatment, and cure. Such a hospital should contain, also, a laboratory for the study of normal and of pathological psychology. I am convinced that progress in normal psychology will be made chiefly through the study of abnormal conditions, just as physiology has profited so enormously through the work of the pathologist."

A word should be said for veterinary medicine and its achievements of enormous economic value in the control of the contagious diseases of animals. The recent achievements of vaccination against the Southern cattle fever and against tuberculosis, the eradication of the foot and mouth disease among other matters, have demanded the highest scientific knowledge and the greatest skill in its practical application.

Unfortunately, veterinary science lacks in this country adequate facilities for research and instruction. "Practically," says a correspondent, "the veterinary sciences in the United States are leading a parasitic existence. We are dependent almost wholly upon the results of investigation and teaching of European countries, notably Germany and Denmark. The value of the live-stock industry here is so tremendous that almost every state in the Union should have a well-equipped veterinary school supported by public funds. There is but one veterinary school in the United States that has anything like adequate support." That this is true shows that our farmers and stock-raisers are very far from having an adequate idea of one of the most important of their economic needs.

Economics

We may justify the inclusion of economics among the utilitarian sciences on grounds which would equally include the sciences of ethics and hygiene. It is extremely wise as well as financially profitable to take care of one's health, and still more so to take thought of one's conduct. The science of economics in some degree touches the ethics of nations and the "wealth of nations," a large factor in the happiness of the individuals contained within them, depends on the nation's attitude towards economic truths. Another justification of this inclusion is found in the growing tendency in our country to call on professional economists to direct national operations. On the other hand, our economists themselves are becoming more and more worthy of such trusts. The inductive study of their science brings them into closer contact with men and with enterprises. By this means they become students of administration as well as of economics. They realize the value of individual effort as well as the limitations which bound all sorts of executive work, in a republic. "Only a few years ago," writes a correspondent, "the teachers of economics were far more generally unfavorable critics of government work which interested them. They have become more and more disposed to coöperate at the beginning rather than to condemn at the end. Just as economics has taken a more kindly and hospitable attitude towards politics, so similarly has it towards business, as illustrated in the rapid rise of courses in commerce." The demand for trained economists in public affairs is "compelling the teachers of economics more and more to seek contact with the men who are grappling face to face with economic problems."

The relation of economic theory to administration is a subject on which there is much diversity of opinion. It is claimed by able authority that "economic science, by becoming ultra-theoretical, has come into far closer touch with practical life than it ever attained before. Laws, the statement of which seems like a refinement of theory, determine the kind of legislation required on the most practical of subjects." On another hand, it is claimed by high authority that our country must have its own political economy. "The generalizations arising solely from the uniformity of human nature are so few that they cannot constitute a science. The classical or orthodox political economy of England was conditioned from start to finish by the political problems it had to face. We are only beginning to acquire our national independence."

Still another view is that "all that has been achieved in the field of economics that is of any value, has been the result of logical analysis applied to the phenomena and experiences of every-day industrial life. The stages of past development can be determined and interpreted only in the light of this analysis. The lesson which the historical economist has never learned, is the importance of that principle, which lies at the bottom of the whole modern theory of evolution, and which was made use of by Lyell and Darwin, namely, the principle that historical changes of the past are to be accounted for by the long continued action of causes which are at this present moment in operation and can be observed and measured at the present day." "This," says my correspondent, "needs saying and re-saying, until it is burned into the minds of all students of economics."

The recent progress of economics in America has lain in part in the development of economic theory by critical and by constructive methods. An important reason for welcoming the exact and critical study of economic theory is this: In the promulgation of imaginary economic principles the social and political charlatan finds his choice field of operation, just as the medical charlatan deals with some universal law of disease and its universal cure. The progress of science in every field discredits these universal principles with their mystical panaceas. There is all the more reason why in politics, as in medicine, those generalizations which deal with necessary laws or actually observed sequence of events should be critically and constructively studied.

In general, however, the progress of economics has followed the same lines as progress in other sciences, through a " minute investigation and the application of principles already discovered or outlined by painstaking inquiry as to facts." This method of work has been especially fruitful in the study of monetary problems, of finance, taxation, and insurance, in the study of labor problems and conditions, in the study of commerce, and in the study of crime and pauperism. In its development economics is, however, many years behind the natural sciences, a condition due to reliance on metaphysical methods and to the inherent difficulty in the use of any other.

"Economics," says a correspondent, "has been less successful than the material sciences in getting rid of the apparatus of metaphysical presumptions. The economist is still too eager to formulate laws that shall disclose the ultimate spiritual meaning of things instead of trying to explain how these things came to pass. He has profited in small degree by those lessons which the progressive evolutionary sciences have driven home in the past in the methods of thinking of workers in other fields. Our science is still sadly behind the times in its way of handling its subject-matter. The greatest and most important work of economic investigations is to make students see things as they are, to fit young men for the more highly organized business new conditions are ushering in, and give a better appreciation of the problems of government and a better training for participation in them."

Says another correspondent: "Training in research is in fact essential to every technical man. The young technologist will be confronted by new problems not covered by anything in literature or in his past experience. Training in research is training in the art of solving unsolved problems, and the practical man who has had discipline of that kind has a great advantage over his more conventional competitors. The Germans recognize this principle, and behold their marvelous industrial growth. The student in every department of science should be taught to think as well as to do."

The time must come when a man who has no training and no experience in research will not be called educated, whatever may be the range of his erudition. To unfold the secret of power is the true purpose of education.

DEPARTMENT XVII — MEDICINE

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(*Hall* 1, *September* 20, 4.15 *p. m.*)

CHAIRMAN: DR. WILLIAM OSLER, Johns Hopkins University.
SPEAKERS: DR. WILLIAM T. COUNCILMAN, Harvard University.
DR. FRANK BILLINGS, University of Chicago.

THE MODERN CONCEPTIONS AND METHODS OF MEDICAL SCIENCE

BY WILLIAM THOMAS COUNCILMAN

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AN acquaintance with present conditions in medicine and with the literature of the past makes us aware of a great change both in the conceptions of medicine and in the methods by which the conceptions are reached. There has been a great increase of knowledge brought about by investigation and experiment, a realization of the value of knowledge and its acceptance and utilization. Medicine has severed all connection with speculative philosophy and taken its true place among the natural sciences. It has been brought into closer accord with other sciences than ever before and has accepted the methods of science. There are no systems, no schools, no paramount authority; no hypothesis is so firmly held that it is not instantly rejected when it fails to accord with new knowledge. Progress in medicine has gone hand in hand with progress in all departments of knowledge.

Medicine has for its problems the cause, the nature, the prevention, the cure of disease. It is a branch of biology in that in all of its relations it has to do with living things. The ontologic conception of disease as a thing differing from and entering into the organism is no longer held, but disease is regarded as a condition of living things in which there is disharmony of function. The phenomena of life depend upon actions exerted upon living tissue by its surroundings. When the action exerted leads to forms of activity which differ from and fail to come into accord with the usual activities, whatever produces such an action is a cause of disease. These causative agencies acting on the tissue, produce structural alterations, in consequence of which even the action exerted by the ordinary surroundings may result in disharmony. The terms health and disease both carry with them the conception of activity. Although the abnormality of function is always associated with and depends upon structural alteration, there may be extensive structural alteration which is so repaired or compensated for that it does not result in disease.

In the history of the advance of knowledge in medicine we find two methods by which knowledge has been sought. In one, the endeavor has been made to form conceptions of the objects studied by means of impressions conveyed by the senses. Great advances have always followed the discovery of methods and instruments by means of which the territory of investigation has been extended. The inquiry does not stop with the mere description of the conceptions derived from the sense-impressions, but an effort is made to correlate them, to ascertain preceding conditions, and the meaning or idea involved. When the inquiry passes beyond the immediate investigation, an ideal conception of the nature, the interrelation, the cause or the result of the conditions studied, an hypothesis, may be formed, based on experience and analogy. The hypothesis must be tested by further observation under natural conditions and by the experiment which involves observation under known and controlled conditions. When the hypothesis has been so tested and found to hold good in all cases under the same conditions, it can be used as a basis from which new questions may arise.

The other method is by speculation. By a wide and illegitimate use of analogy conceptions are formed and projected into the objects, instead of being derived from the sense-impressions. A tendency to speculation is inherent in the nature of man. Confronted always with the unknown, which has such enormous proportions compared with the known, and so much of which seems to be removed from the possibility of actual investigation, man is led to attempt to answer the questions which the unknown thrust upon him by means of the imagination. As knowledge becomes deeper and more extended, speculation tends to become more confined. True philosophy aims at a complete understanding of the causal relation of all processes in nature and of man's relation to these processes. Disease, as one of the most important conditions in nature affecting man in all of his relations, has always had an important place in philosophy. All the systems of philosophy in the past, from Plato down, have embraced speculations concerning disease. The true ends of philosophy cannot be reached by speculation, but by the use of all the material for observation given by the natural sciences, and a philosophic system will contain just so much truth as there is natural science in it. Nature seems to delight in refuting all conceptions of her processes which are not based on sense-impressions.

The progress of knowledge by these two methods has been the same in all sciences as in medicine, but it is more easily followed in medicine, because of the important place which its subject disease has always held in the thoughts of man. It is possible to trace the past in the conditions of the present. In the earliest period of medicine, before there were any records of the study of the phenomena of disease and any differentiation of disease, disease was regarded as the visitation of the wrath of offended deities, and the surest mode of its relief the propitiation of the deity by supplications and offerings. Such beliefs are still held, or at least practices which were based on such beliefs are continued. In almost all countries at the present time it is the custom to offer supplications that the disease of an important individual may be removed by divine interposition. It is true that such prayers may be a part of past tradition or a part of the discipline of a religious system, but undoubtedly their efficacy is believed in by many. Disease has played an important rôle in systems of religions, and the teachers of the system who had most fully embraced its tenets were supposed to be the most efficacious in removing disease. Christian Science is only one of a great number of religious systems held to-day in which treatment of disease forms an important part of the cult. In the past there have been systems of medicine which gave explanations of all phenomena, and the system being perfect the phenomena were removed from further investigation. Homeopathy is the most important survivor of such speculative systems.

Speculation has undoubtedly been fostered by systems of religion founded on what was accepted as supernatural revelation. Revelation which sufficed for the explanation of phenomena at the time when it was given becomes firmly and inseparably blended with speculation when it must be expanded to meet a wider range of phenomena. Knowledge cannot be diffused, accepted, or utilized beyond the general development of culture. Any general influence which can be exerted on the people, turning thought into new directions, giving new subjects and proper methods, is of great importance. Darwin, by substituting a rational and easily comprehended hypothesis, based on observation and experiment, with a clear statement of the method by which the hypothesis was formed, for a revelation which did not suffice and which could not be twisted to conform to what was of general and accepted knowledge, exerted probably the greatest influence on general scientific progress in the last century. Medicine, like all other sciences, has felt its vivifying influence.

One of the greatest changes which has taken place in the last century is the general acceptance of the idea that medicine is a natural science, in which knowledge must be sought by the methods of science, namely, observation and experiment, and that disease is the result of injurious conditions acting upon the tissues. A great part of the mystery surrounding disease has been removed by knowledge of the conditions which give rise to it, with the further knowledge that it is possible to prevent disease by removing such conditions. Even though some may still believe that an epidemic of typhoid fever is an act of God, they must see that the action is exerted by means of a defective water-supply, and the surest way of removing the epidemic is not by supplication, but by purifying the water. At no time in the world's history has the importance of knowledge been so fully recognized as at present. People see the application of knowledge in the arts, and that improvement in the processes involved is directly dependent upon increased knowledge of the processes. There is a closer union between science and art than has ever been before. We see the influence of the appreciation of knowledge in medicine in the general acceptance of the idea that the hospital, in addition to taking care of the sick, shall furnish facilities for the investigation of disease; in the creation of institutes devoted to the furtherance of medical knowledge, and in endowments of universities to the same end.

A brief glance at some of the more important periods in medical history will enable us to trace the influence and the results of the two methods by which knowledge has been sought. The history of medicine begins with Hippocrates. Before him there were only superstition and tradition without systematic observation and description. He described accurately the results of his study of the phenomena of disease, classified the phenomena, and based his methods of treatment on his observations. The influence of Greek philosophy made him attempt to explain the phenomena, by the assumption of a force residing in and presiding over the body. The contemporaries and successors of Hippocrates who regarded him as a god, and his conclusions as unfailing axioms, entirely neglected the methods by which he arrived at them. It must ever remain a source of wonder that the light which burst upon medicine with the advent of Hippocrates should so soon have passed into darkness. The Greeks chose rather to speculate on the meaning of phenomena than to investigate them. Galen, next to Hippocrates, had the greatest influence on medicine, an influence which was dominant for more than 1300 years. Galen mastered all the knowledge and traditions of medicine at his time and made important contributions to anatomy and physiology. He was the first to introduce the experimental method into medicine, and gave a firm foundation to nerve physiology by observing the paralysis of certain muscles after section of the nerves. A voluminous writer as well as investigator, Galen created a complete system of medicine which remained as authority until men became bold enough to throw over authority when it did not conform with what could be learned from investigation. The stagnation and decline in medicine which followed Galen and continued during the Middle Ages was due to the dominance of a dogmatic religion in lands in which the general culture of the people should have given the conditions for knowledge to increase. The Church regarded its dogma as sufficient, and all inquiry, all free activity of men's minds were prohibited. Dogma based on supposed revelation sufficed. There was some attempt at progress made by the Arabians, but their most important contribution was the preservation of the old learning. Even the period of the Renaissance passed with little or no influence on medicine, for mental activity was turned exclusively into channels in which dogma could not be disturbed.

Three circumstances served to bring about a new era in the progress of knowledge in which medicine shared. The discovery of the art of printing by which knowledge became more diffused and more exact by the substitution of record for tradition, the discovery of America, with the stimulation which this gave to thought and imagination, and the Reformation, which gave freedom to thought, removed the weight of authority, and allowed investigation. The reform in medicine was introduced in Europe by Paracelsus, whose work was chiefly the overthrow of the Galen system, which had sufficed and under which investigation was not possible. Progress in the new reform was more active in England than in the land of its birth. This was due to the freedom from war, the greater freedom of the people in all ways, and to the work of Francis Bacon, who for the first time showed clearly the methods by which knowledge must be sought. With few exceptions, English medicine has remained true to the precept of Bacon, that knowledge increases by the observations of things with the proper utilization of past observations. There has been an almost continuous line of great physicians in England who have enriched medical knowledge by investigation and who remained free from speculation. The contributions which such men as Harvey, Sydenham, Hunter, and Bright have made, remain and have served as bases from which knowledge has grown. The theories which were founded upon their work have passed without influence. That there came a time in England when medical investigation was greatly surpassed in other countries, is to be attributed to the introduction of methods of investigation which could not be utilized in England. It was the introduction of the laboratory with the facilities for and the systematization of medical investigation which gave medicine in Europe its ascendency. Young men at an age when authority has the least weight, and before there was opportunity given them for the investigation of the clinical phenomena of disease, found in the laboratory opportunity for investigation, and had small questions placed before them which could be solved. The laboratory gave the workers scientific methods which formed the basis, and gave the direction of further work in the clinic. With the laboratory came also a division of labor, which allowed certain men to devote their time to investigation and teaching. Ambition was stimulated, for advance and the further career was made dependent upon the ability for investigation.

It is interesting to follow a wave of speculation in medicine which reached its acme in Germany in the early part of the nineteenth century. In the period following the Reformation the most striking figure in medicine was Albrecht v. Haller, a man who as investigator and clear thinker has been equaled by few. Haller recognized the important fact that life was a property inherent in the tissues and manifested itself by sensation and movement. On the work of Haller is founded the system of Brown, who though a Scotchman can be regarded as the forerunner of the German *Natur-philosophie* in medicine. The system of Brown is founded on the principle, which he states clearly, that the living animal body is distinguished from the dead and from all lifeless matter by the capacity for excitation by external influences. The difference between health and disease lies in the degree of irritability of the tissues. He divided disease into the sthenic and asthenic types, according to the degree of irritability developed by the excitant, and the treatment of disease was based on this. In the hands of Brown's pupils and successors treatment of disease was productive of great harm. The theory of Brown found ready acceptance in Germany, not only by physicians but by a group of men who sought to explain nature by the creation of laws. The law once made was regarded as more correct than the observation. Schelling, who was the foremost figure in this philosophy, sought to give a representation of all the phenomena in nature, to develop the interrelation of the phenomena, to show the action of natural laws in all bodies, and believed that these laws originated in a common point and were characterized as an advancing series of higher phases of development of matter. Not only was it impossible to construct a system of the world from the knowledge of nature at that time, and it probably never will be possible, but Schelling very imperfectly utilized what knowledge there was. This *Natur-philosophie* dominated medicine in Germany during the first quarter of the nineteenth century. It is expressed to a greater or less extent in all medical writing. The most gifted men could not entirely withdraw from its influence. Medicine was not a science following the methods of observation and experiment, investigation was banished from the clinic and laboratory and found its place at the writing-desk. Hartmann says that one reason why the *Natur-philosophie* found such ready acceptance was the ease with which it was possible by its aid to become famous as a writer. The young physician found it no longer necessary to become acquainted with the material for study by toilsome investigation; he only needed the philosophic forms of expression and could apply these to what he knew or did not know of medicine. Many systems of medicine were founded which purported to give a complete explanation of all the phenomena of disease. Of all these systems, the one which has endured the longest was almost the most fantastic in its structure. The success of the system of Hahnemann or homeopathy is, in the first place, due to the fact that under it the treatment of disease represented a great advance as compared with treatment under the systems of Brown and Rasori. However zealous the exponents of a system may be, it will find its condemnation from those who suffer most from it. The system as presented by Hahnemann was complete; it offered names and seeming explanations for all conditions. The practice of the medical art under the system was easy and involved no toilsome investigations. It was put forth at an early period of the *Natur-philosophie* and was carried upward on the tidal wave which swept through Germany. It at once found great favor with the people and was taken up by great numbers of physicians. In the course of time the adherents of the system have become divided into three camps. In one its principles have been extended far beyond the conception of Hahnemann, in that the products of disease have been used as remedial agents; a second have remained true to the principles of the founder; and a third, comprising a large number of intelligent physicians, hold only to the name. Under the *Natur-philosophie*, combinations between religion and medicine arose and a system, which represented a return to medieval mysticism, was formed by Windischmann and Ringseis. In this it was taught that the causes of disease are immaterial and not to be sought for, since disease merely represents discord between body and soul.

Such a remarkable phenomenon as the dominance of the speculation which was a part of the *Natur-philosophie* must be regarded as a part of the romantic movement which swept through Germany and found its chief expression in poetry. All barriers to idealism and speculation were cast aside. The movement was a part of the awakening of Germany to a new national life. The great questions of the time involving political liberty and even national existence were absorbing. Under such circumstances only a few could turn from the pressure of such large questions to the narrow field of scientific investigation. It is remarkable that the great awakening in France which preceded it should have been characterized by the opposite tendencies. During this period of speculation in Germany valuable contributions to knowledge were continually being made in anatomy and physiology. The chief exponents of the *Natur-philosophie* were physicians who had to do with the clinical phenomena of disease. Speculation was fostered because the methods of gaining information from the study of disease were at the time so meager that observation was restricted. So confirmed was the habit of speculation that each new discovery in anatomy and physiology, instead of serving as a basis for investigation, became food for new speculation.

It is possible to see the influence of the *Natur-philosophie* on its greatest opponent, Rudolf Virchow. No one more clearly laid down the methods of scientific investigation than did Virchow in the opening articles of his *Archivs.* He was a born investigator and made valuable contributions to knowledge in every department of medicine. The protocols of his autopsies are models of full and accurate descriptions of observations. He made important additions to the technic and methods of work by the use of which new knowledge was gained. He was a great teacher as well as investigator, and men trained in his methods are among the most famous in medicine.

It is difficult to find in the history of modern medicine any one who can be compared with Virchow in the contributions made to medical knowledge and the influence which he exerted. He substituted for the ontologic conception of disease, which was prevalent in Germany at that time, the conception which we adopt to-day, that it consists in life under altered conditions. This is not an explanation, but a simple way of stating the summation of the most obvious phenomena. He created the cell theory of disease, which, though it represented an enormous advance over prevalent theories and has been most stimulating to investigation, can no more be held in its entirety as Virchow gave it than any of the systems it supplanted. Unlike the other systems, it did not pretend to be all-satisfying and all-explaining. The cell theory of disease should be regarded as an hypothesis fully justified in being formed from the knowledge at that time available. In Virchow's theory of inflammation we see the great value of an hypothesis which, though gradually proved incorrect by continued observations, has been most stimulating to investigation. It is interesting to see the contention which has been excited by theory. No one contends for the acceptance of an observation, but is content to leave this for time, but the contention is for the conception based on the observation and the theory formed from the conceptions. Virchow properly opposed the ontologic conception of disease, but this led him also to oppose the proof given that certain diseases which he regarded as due to the action of general causes, were due to parasites. Virchow appeared in medicine at the time when *Natur-philosophie*, though seemingly dominant in Germany, was really far advanced in decline, and his mighty blows were delivered against a feeble body. It was the knowledge of French and English medicine, where the advance had been by investigation, the increase in knowledge in all the natural sciences giving too much to be covered by any system, which gave the death-blow to this period of speculation in medicine.

It is possible now to see the effect of this period of unrestricted imagination on medicine. It is true that it inhibited progress, by restricting observation and experiment, that it substituted theory for knowledge, and found satisfaction in empty phrases and juggling with terms. But it gave birth to fruitful stimulation, and opened wide and distant vistas which science has utilized. The excitation of the imagination, provided the imagination be controlled and theories be recognized as theories, is most useful in science. Without the imagination, without the tendency to seek for explanations of phenomena, there would be no progress. There is only danger in the failure to recognize the true relation of the hypothesis and in attempting to progress by adding hypotheses. There was but little progress in the period, but progress resulted from the stimulation which the period gave, and from the reaction which followed it. Although as playing a great part and affecting an entire people, such a movement has passed and will probably not return, we constantly see the same tendencies. The medical systems, often connected with religion, which are constantly arising in all countries, and especially in this, the attempt to form theories in explanation of the unknown, are due to the same mental states which produced the *Natur-philosophie*. They arise, have a ready following composed of birds of passage resting temporarily on any bough provided, and disappear without making any real impression. How completely the period of the *Natur-philosophie* has passed in the country of the creation is seen in the history of medicine in Germany for the last fifty years. By the adoption of scientific methods, by the fostering influence of the government, which provided facilities for research, and by a system which gave reward for investigation, Germany has become the leader of the world.

At no time in the world's history was there such rapid advance, such a complete transformation in methods, such an array of great men in all the departments of medicine as in France, following the Revolution. The foremost of the men in this school in France was Bichat. He undertook the gigantic task of creating for medicine a solid foundation derived from the study of objects and from experiments. He carried the anatomic study of disease further than ever before, endeavoring to ascertain not only the lesions in the organs, but in the tissues which compose them. The relation between the anatomic lesions and disorders of function he says must be studied by experiment. The work of Magendie in physiology was hardly less important than that of Bichat in pathology. Physiology had suffered from the theory of vital force which as a seeming explanation weighed upon it as an incubus, opposing investigation. He claimed for physiology the same methods as in physics and chemistry, saying that the carefully conducted experiment is alone decisive in testing the conclusions formed from observation of phenomena. The work of Magendie had full recognition in France, and he was followed by Claude Bernard and Brown-Sequard, who further developed his methods. Corvisart, Andral, Louis, Rayer, and Cruvilhier were among the most brilliant men in the new school which was founded by Bichat and Magendie. Corvisart and Laennec deserve especial mention in that the former brought to general knowledge the method of percussion of Auenbrugger, which had been forgotten, and the latter introduced and further developed the method of auscultation.

In the advance of science new technical methods of investigation play a most important rôle. The technical method enables the observation to extend further and more deeply. Virchow has said that the introduction of the microscope into medical research enabled us to approach several hundred times nearer disease than before. The microscope introduced a new era in the study of disease; it came into general use when the study of gross pathology in the absence of new questions had almost reached its limit. It gave more correct ideas of disease by increasing the powers of observation; it overthrew at once many theories and gave new points of view and new questions, from which further observation could proceed. Every improvement in the microscope by which its efficiency is increased has the same influence. The knowledge of the influence of bacteria in disease is due, in the first instance, to the improvement of the microscope, and in the second, to the discovery by Koch of methods of cultivation, by means of which the individual species can be studied. Until this was possible our knowledge of bacteria was inexact and their causative relation to disease only an hypothesis. The development of knowledge of the minute structure of cells and tissues is principally due to the use of methods of staining, which started with the simple carmin stain of Gerlach. In clinical medicine the introduction of the microscope, the thermometer, the methods of chemic investigation, the blood-counter, the Röntgen ray, have all led to a closer insight into disease and the substitution of knowledge for conjecture. There is a further indirect advantage which comes from the use of instruments of precision in investigating phenomena, in that the continued use of the methods, the constant seeking for exact knowledge of conditions removes the tendency toward speculation.

The brilliant results which have been reached in surgery, changing this from the most despised to the leading branch of medicine, show the advantage of methods which are founded on knowledge. Surgery was despised in the period in medicine in which speculation was in the ascendency, when the answers to its problems were sought in the study rather than at the bedside and in the laboratory. The art of surgery has been dependent upon direct observation of disease, and its remedial measures were applied to the disease as revealed by sense-impressions. Theories and systems in medicine have come rather from internal medicine, in which field the diseased conditions were not so susceptible to study as things. The broken leg, however, is revealed by sight and touch, the tumor is an object. Moreover, the training in the anatomic and other laboratories so essential for a surgeon, gave the knowledge and the methods, and the manual skill to make them effective. At an early period surgery had recourse to animal experimentation, for the animal body offered the readiest means for testing new devices. In surgery new knowledge has been readily accepted and utilized. The demonstration of anesthesia came first from the surgeon, and the surgeon was the first to accept and apply the knowledge that infection is due to the action of living organisms. By the use of anesthesia and of measures of preventing infection, surgery has been extended into fields formerly supposed not to be open to the exercise of its art. Medicine owes a debt to surgery for not only what it has accomplished, but for holding to proper methods and demonstrating their importance. The less advance in modes of treating disease which internal medicine has made, compared with that made in surgery, is to be attributed to the difficulty of obtaining definite knowledge of the conditions of disease in internal organs.

That the lack of power is due primarily to lack of knowledge is shown by the fact that for diphtheria, formerly one of the most dreaded, now probably the best-known of diseases, there is a remedy which leaves little to be desired. The production of antitoxin is the greatest triumph of scientific medicine and is due to knowledge obtained by the application of scientific methods to the study of a disease which gave unusual opportunities for investigation. It points out what may be accomplished in the future by not seeking for analogies between other diseases and diphtheria, but by pursuing the same methods. Modern therapeutics is guided by two principles in each of which efficiency is dependent upon knowledge of disease. In the most important, the remedial agent has a specific action on the cause of disease, either destroying it or opposing its action. In the second, the remedial agents are used not with the view of exerting any specific action against the cause of disease, nor even in assisting in the restoration of the tissue which has been injured, but with the view of restoring function. Any agent acting as a cause of disease produces injury of the tissue, and the effect of this is alteration, or diminution, or destruction of function. There is a close interrelation of function, that of one organ depending upon the others. The effect of the alteration of function is seen in the supervention of phenomena, which differ from the ordinary. The effect of impaired function may be remedied by supplying the body with some substance which was formed by the impaired organ. Substances directly derived from glands in the animal body, such as thyroid and pancreatic extract, may be supplied. Or the functional activity of an organ may be increased by direct stimulation or increasing its blood supply. Or the function of some other organ nearly related to the organ affected may, by increased function, be caused to supply the deficiency.

Therapeutics acts either as a guard against, or as a caretaker of the body in disease. Its greatest triumphs are in prevention. When the injury has once been produced, its effects are minimized by the capacity of the body to adapt itself to new conditions. There is a third use of therapeutics in the case in which the disease produces so much pain and discomfort that the remedial agent is used for the purpose of diminishing the effect of sense-impression on the central nervous system. It is clear how complicated the questions are, and how much greater is the task presented to the physician than to the surgeon. The surgeon acts directly, either adjusting parts which are deranged or by removing tissue which is diseased. The study of medical literature shows the mistakes and follies which have been and are being perpetrated in therapeutics. The more obscure the disease, the greater the number of remedies; the more ignorant the practitioner the more confidence that certain drugs will act as remedies in all diseases. Each year has served to discard some remedy considered infallible and to substitute for it another equally infallible. The discontent of the general public with such therapeutics is shown in the success of charlatans who advertise nostrums for the cure of all diseases. It is just as easy for them to obtain certificates of cures by the nostrums as it is for the practitioner to become convinced of cures effected by certain favorite drugs.

The greater knowledge of the infectious diseases which has come with their experimental study has especially served to place therapeutics upon a proper basis. It has become apparent that many diseases are self-limited and tend to recover under any treatment, provided this be not too injurious, and that the medical art can be more successfully exerted in preventing disease than in its cure. The first effect of increased knowledge of disease was to produce a feeling of powerlessness in the face of it, followed by a nihilism in therapeutics which was as much to be deplored as overconfidence, for it acted as a bar to progress. This nihilism was a prominent feature of the Vienna school in the sixth decade of the past century. The science of therapeutics as we find it to-day is founded on experimental pharmacology and pathology. In experimental pharmacology the action of drugs on the healthy animal is investigated. It is sought to discover the mode of entry of the drug into the tissues, the mode of excretion, the changes the drug undergoes while in the body, and the changes in structure and function it produces. The action of the drug may differ in different animal species. Knowledge of the pathology of disease shows in what part changes are produced by the causative agent, the nature of the changes, and the effect of these changes on function. The determination of what is taking place in the body in disease is the most important question in medicine to-day. For its answer all the resources of science must be brought to bear. The subject is rendered more complicated by the fact that we are not dealing with a fixed but with a variable quantity. Age, heredity, temperament, and social environment must all be considered. We cannot say, except with wide limitations, what changes and variation in function will be produced by the action of certain conditions. With the knowedge of the effect of the drug on the healthy body, and the knowledge of what changes are being produced in disease, and the effect of which we wish to minimize, an intelligent experiment may be made. Previous experimentation on animals should deprive the experiment of all danger.

Another change which has become apparent is the greater specialization not only in the exercise of the medical art, but in investigation. All increase of knowledge must bring with it specialization, for with the enlargement of the field comes the impossibility of its control by one individual. Specialization has both advantages and disadvantages. The advantages are, that investigations are more easily carried out by the simplification of the questions and the familiarity with technical methods. Methods of investigation have become so complicated that the necessary skill can only be attained by the constant exercise of methods only applicable in a very narrow field, and an investigator of exceptional ability in one line of work may be powerless in another. A man may profitably devote his entire energies to the study of the changes in nerve cells in disease, or may confine himself to the study of a single species of bacteria. With the enormous increase in medical literature there has come specialization in this, and certain journals are devoted to special subjects and are only read by those working in the field covered. The first differentiation came in the separation of anatomy, physiology, and pathology from practical medicine, that is, the medicine concerned with the exercise of the art. The separation was a natural one, for not only could progress be more rapid, but the subjects could be better taught by one who had the knowledge which came from his own investigations. It is no longer possible for a single individual to control the knowledge in any of these primary subdivisions. The most obvious disadvantage in specialization is the loss of the more general aspects of questions. The large questions become broken up into smaller, and the smaller questions become leading questions to be again broken up. It is also felt that the knowledge gained in such special investigations may not be of a character which can be utilized in the treatment of disease. But few of the questions which arise and form the basis for investigation come from the clinic, and they apparently have only the most remote relation to the problems of disease. The investigator very properly feels that his investigations are justified, in that they form contributions to general knowledge, and whether or not the results are directly applicable to the treatment of disease does not disturb him.

There was an error perpetrated in not giving to those devoted to the study of the clinical aspect of disease the same opportunity to devote themselves to research, to answer the question which came from the phenomena of disease, which was given to anatomy, physiology, and pathology. Clinical medicine, the study of the problems of disease coming from the bedside, must have the same opportunity and must advance by the use of the same methods as physiology and anatomy. Clinical medicine is behind the special departments in the contributions it has made to knowledge, in the methods by which it seeks to advance, and in the efficiency of teaching. Provision must be made in the universities which will enable men in the clinical departments to devote themselves to research and teaching, and laboratories must be provided for such research. Only one who is himself an investigator can direct investigation by recognizing and properly stating the questions. There need be no fear that the knowledge which comes from investigation will not be utilized. In what way may not be apparent at the time. Often knowledge which seemed furthest removed from utility has become the most important. That knowledge is power, and that it is the only power is an accepted axiom.

Anatomy and physiology, originally arising from human medicine for the furtherance of knowledge which could be applied to the treatment of disease in man, have long outgrown such limitations. Both have become comparative. Physiology undertakes the study of the processes taking place in living things, anatomy their form and structure. The comparative view has more slowly entered into pathology, for this has been more closely in contact with clinical medicine, and mostof the questions for investigation have arisen in connection with the diseases of man. Disease is found in every living thing, in all animal and plant life. The phenomena of disease must differ according to the conditions peculiar to the organism. Strictly speaking there can be little similarity between the phenomena of disease in a plant and in an animal. The functions that are destroyed or altered by disease are too dissimilar. But this is not true when we study the closer details of disease. In both, changes are produced and the changes affect function. We can study unicellular organisms directly under the microscope, see the changes which are being produced by injurious conditions and the effects of the changes. Knowledge derived from such study may be said to be the basis of our conception of inflammation. The studies of plant diseases have been almost entirely directed from the economic side. The economic results which have come from this study by enabling the prevention of disease are almost incalculable. General medicine has gained by this study a greater knowledge of parasites, their mode of action and the means by which the organism is protected against them. That the knowledge has been so rapidly gained is due to the facilities for investigation and experimentation. Plant experimentation has never given offense. It should be regarded on the whole as very much better that the study of plant disease has been directed from the economic side, for progress has been more rapid, but there would be advantage in the closer association of plant and animal pathology and the extension to plant diseases of questions coming from disease in man.

Careful study of diseases in animals has been chiefly directed to the infectious diseases and especially to those artificially produced. The questions have been chiefly those concerned with the parasitic cause of disease and the mode of action of the parasites. The more obscure diseases of animals have attracted but little attention and only from the economic side. The phenomena of disease in the higher animals have much similarity to the phenomena of disease in man, and in certain aspects the diseases of animals are more capable of investigation. Diseases are found in animals which are similar to the most obscure diseases in man. Our ignorance of these diseases in man is due to their complexity and the difficulties of investigation. To their understanding chemical and physical methods are necessary, and some of these methods cannot be carried out, for they may be harmful to the individual. In animals we have the advantage that the disease can be interrupted at any stage and the conditions studied at this stage. We know the infectious diseases of animals chiefly by their experimental production. There has been but little study of these diseases under natural conditions and much knowledge can be gained by the mode of, and conditions predisposing to, infection. Questions of heredity have an important bearing on disease. The susceptibility of animals to disease varies. Common experience has shown in man also that, under circumstances apparently the same, certain individuals will acquire diseases, others remain exempt. There is also foundation for the belief that susceptibility for certain infectious diseases is inherited and in other diseases inherited susceptibility is beyond doubt. The most striking recent discovery in medicine is that the blood-serum contains many complex substances. Some of them play an important rôle in the animal economy, for others we can as yet discern no purpose, and our knowledge of these substances is chiefly confined to their effects, but it has recently been found possible to isolate one substance in pure form with a known chemic composition. While these substances may serve an important rôle in protecting the body against disease they may act in the opposite way by providing a means by which injurious substances are brought in contact with cells. Whether chemic variation may not arise, be inherited, and play an important part in disease susceptibility is an important question to be answered by comparative medicine. For the purpose of such investigation an animal clinic is necessary, which should be provided with thorough facilities for the study of disease. The questions for solution should come both from comparative medicine and from the clinic of human disease.

Comparative medicine is intimately associated with experimental medicine. There can be no contention as to the relative advantages of observation and experiment. The experiment is only observation under simple and known conditions and supplements observation under the more complicated natural conditions. In the experiment it is possible to divide questions into their simpler components and make each the subject of experiment. In experimental medicine just as in the animal clinic, the questions for solution should come from both comparative medicine and the human clinic. The most brilliant results in experimental medicine have come from the study of the infectious diseases. Knowledge of these diseases stands in direct relation to the possibility of their experimental production. It is true that we have not been able to produce in animals many of the diseases which are found in man. Experimental medicine is comparatively new and the number of animal species experimented upon has not been large. It has recently been found possible to produce syphilis in the chimpanzee and there is every reason to hope that this will lead to knowledge of the nature of this most obscure disease. Questions concerning the circulation and respiration in disease which are closely related to physics will find their answer in experimental medicine. The opponents of animal experimentation should remember that the greater our knowledge of disease which comes in this way, the further will disease in man be removed from experiment. Before our present knowledge of diphtheria, tuberculosis, tetanus, and anthrax, all treatment of these diseases was experimental. In certain cases experiments must be carried out in human beings and even when the experiments may have a fatal termination. Such experiments will only be resorted to when this forms the only method of obtaining knowledge of the highest importance, and the subjects of the experiment must be adults who submit with full knowledge of the possible consequences. Let us give all honor to the men who devised and the brave men who submitted to an experiment, the knowledge obtained from which has placed yellow fever in the list of preventable diseases.

There has been in the past too wide a separation between the public and the medical profession. The public has derived its medical information chiefly through the newspapers and the information so given has been sensational and unreliable. Without correct information of the problems which face the medical profession and of the methods by which these problems are being solved, neither the sympathy nor coöperation of the public may be secured. Active or passive opposition may be encountered. There is evidence that this is being slowly changed. The medicine of the romance is not so fantastic as it was formerly. The general information in biology, human anatomy, and physiology necessary for any appreciation of medicine is being imparted by the schools. Many of the popular magazines contain admirable articles on disease. The stories of such diseases as malaria and yellow fever have actual fascination. The medical education of the public is also furthered by the work of boards of health in the control of infectious diseases. The public is slowly but none the less surely learning that disease is not a mysterious entity, dwelling like a devil in the body, to be driven out by the use of some equally mysterious agent, but a condition of life which can be guarded against. The public is not slow in the appreciation of the results of the work of boards of health, and is willing to make provision for their work.

Medical education, the training of men to exercise the art of medicine, has been revolutionized in the past twenty-five years. The most marked change has been in the substitution of object-study for the didactic lecture. The didactic lecture is still used, though not with the idea of imparting knowledge, but of showing the interrelation of knowledge coming from objective teaching. The successful practice of medicine depends more than ever before upon the use of methods which give accurate knowledge of the condition of the sick individual, and training in the exercise of these methods is the most important part of medical education. It is certainly of importance that the student should learn the structure of the body, the functions of the different organs, and the changes which organs and functions undergo in disease. The knowledge acquired will be constantly used in solving the problems presented in the practice of medicine. While this is true, a great part of the value of these studies consists in the discipline which laboratory study enforces.

In the laboratory the student learns to acquire conceptions of objects and of the activities taking place in them, by means of sense impressions, and to use and appreciate methods by means of which the field of investigation is extended. He learns to approach problems from the scientific point of view. Progress and success in medicine is directly dependent upon the habit of investigation. Medicine is not and probably will not be an exact science with definite laws, by the application of which the exact sequence of phenomena can be foretold. Every case of disease is a problem, and on the knowledge acquired from investigation successful treatment of the individual depends. Science demands to know, and methods by which knowledge can be obtained are of supreme importance. Methods of obtaining knowledge have been widely extended in clinical investigation. Every year sees the discovery of new methods. There should be, and with the foremost men there is, no distinction between the clinic and the laboratory. In both knowledge is sought by the use of the senses, and methods of investigation have a supreme importance. The laboratory discipline can be given just as well in the clinic as in the other laboratories, with the advantage that the methods of the clinic are the methods which are used in the practice of medicine, and facility in methods can only be acquired by continual exercise. It is evident, however, that the laboratories and clinics should only be conducted by men who themselves know and fully appreciate the importance of methods. It is probable that in the medical education of the future there will be a restriction of the laboratory training in anatomy, physiology, and pathology, and an extension of the training in the methods of the clinical laboratory.

THE DEVELOPMENT OF MODERN MEDICINE

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MODERN medicine is a composite of the knowledge of many sciences. The last twenty-five years mark the period of the greatest evolution of medicine in its history. The foundation of modern medicine was laid by the labors of hundreds of earnest workers in the field of science during the last three centuries. As a rule the value to modern medicine of these pioneer investigators was in an inverse ratio to the length of the period which separated them from modern times. Exceptions to this rule are found, however, even in the seventeenth and eighteenth centuries. Indeed, at that period when one considers the superstition, prejudice, mystic belief, magic, astrology, dogma after dogma, and system after system which prevailed, the inheritance of the dark ages, our admiration is excited by the really great results of the work of some of the scientists. Until the seventeenth century, Hippocrates, Galen, and Aristotle were the authorities in medicine. There was practically no advancement in medicine in that period of time. Anatomy and pathology were not understood; dissection was forbidden by the clergy of the Middle Ages, because it was considered impious to mutilate a form made in the image of God. Dissections of the human body were practiced to a limited degree during the fourteenth and fifteenth centuries, but the sixteenth century was marked by the birth of Vesalius, a naturalist, whose investigations in human anatomy marked the beginning of scientific medicine.

The seventeenth century marked the birth of realism. Galileo was a reformer in physics, and other scientific men broke away from the superstitions and dogmas of the day and searched for light along self-chosen paths. During the century, Harvey discovered the circulation of the blood. Zoölogy and botany were cultivated. Romer calculated the velocity of light. Lord Bacon's brilliant mind shone resplendent. Sir Isaac Newton discovered the law of gravity. Malpighi, Steno, Bartholin, De Graf, Wharton, Nuck, Brunner, Wirsung, Peyer, Havers, Cowper, Schneider, Hewson, Vieussens, and Merkel, and many others, dissected out everlasting monuments of their genius and skill. Hooke introduced the term "cell," and the cell-doctrine was founded by Malpighi and Grew. Linnaeus, Kant, Richelieu, Mazarin, Molière, Bach, Hayden, Beethoven, and Goethe were contemporaries of these other great men. Peruvian bark was introduced into Spain during this period.

The eighteenth century, called the golden age of medicine, witnessed a continuation of the constructive and realistic work of the previous century. Pathologic anatomy was born, and in the person of Morgagni received an impetus which gave it everlasting life. John Hunter, Baillie and Home in England, and Bichat in France were worthy successors of Morgagni. In this century Leopold Avenbrugger, the discoverer of percussion as a means of diagnosis of the diseases of large organs of the body, introduced the method in clinical investigation. Haller originated experimental physiology. An ambulatory clinic was inaugurated at Prague in 1745, and the first clinical institute was founded at Vienna in 1754 by Van Swieten. Preventive inoculation against small-pox was performed, a method of protection against variola which was practiced by the Chinese a thousand years before Christ. The most notable event of that period occurred at the close of the century with the discovery, by Edward Jenner, of vaccination as a protection against small-pox.

The period marked by the first seventy-five years of the nineteenth century was but a continuation of the tendencies of the preceding period. The watchword of medicine was pathological anatomy and diagnosis — the so-called scientific or exact medicine. This tendency to realism was modified to some degree by the philosophic teaching of Schelling, Hartman, Spencer, Haeckel, Hagel, and others. Pathologic anatomy found brilliant exponents in Bretonneau, Corvisart, Bright, Rokitansky, Louis Magendie, and many others. The practical salutary effect of pathology upon practical medicine was evinced by the epoch-making clinical observations of Addison, Graves, Cheyne, William Stokes, Trousseau, Wunderlich, Ziemmsen, Corrigan, and others. Notable was the advancement made in physical exploration in diagnosis. Avenbrugger's invention of percussion was extended by the translation of his book and the adoption and improvement of the method of percussion by Corvisart.

In 1815, Laennec invented the stethoscope. Skoda developed both percussion and auscultation and published his famous work on these subjects in 1839. Thus in medicine we find that, even in that early day, the pathologist and the clinician taught that by the aid of its special senses and by the microscope and instruments of precision the diagnosis could be made with a definiteness, impossible by the use of the symptoms alone.

The epoch-making work of Johannes Mueller in embryology and physiology marked the beginning of modern physiology, and this, with the unparalelled activity of Virchow in pathology, resulted in an enormous development of scientific observation and productiveness.

Corresponding activity marked the work in the sciences of chemistry, zoölogy, comparative and human anatomy, physics, botany, and general biology. The development of the microscope gave impetus to the study of the lower forms of life. In 1838, Ehrenberg regarded infusoria as animals. In 1852, Perty claimed that most infusoria should be assigned to the vegetable world. Cohn proved the correctness of this conclusion and perfected a classification. In 1837, Bassi discovered the parasitic nature of silk-worm disease. The parasitic form of favus and thrush was proved by Schoenlein and Nagel respectively. Dovaine recognized the anthrax bacillus in 1850. In 1857, Pasteur demonstrated that fermentation and putrefaction were caused by lower organisms and at the same time forever set at rest the superstition of spontaneous generation. Obermayer recognized the spirillum of relapsing fever in 1873. Bacteriology became an exact science with the discovery by Robert Koch of cultural methods which made the differentiation of germs possible.

The causative relations of bacteria and microörganisms to all infective processes has been proved by the laws promulgated by Koch. The discovery by Brieger, Panum and others of the poisons produced by bacteria was another important step in the progress of bacteriology as related to medicine.

From the discovery and development of bacteriology, and especially through the brilliant researches of Pasteur and Koch and of their students, has resulted a knowledge which has revolutionized and marked the birth of modern medicine.

Parasites

The discovery of the hematozoön of malaria by Laveran; the recognition of the ameba of dysentery by Loesch; of the ray fungi and especially the actinomyces as infective agents in the lower animals and in man and the more exact knowledge of other animal parasites infecting man and animals, which the microscope has made clear, have been as epoch-making in parasitology as the discoveries of Pasteur and Koch in bacteriology.

The recognition of the relation of bacteria, protozoa, and animal parasites to infective disease has been the means of a more exact knowledge of the clinical phenomena of disease, of morbid anatomy, of physiology, and of physiologic chemistry than would have been possible without it.

Transmission of Infection

The knowledge of the cause of disease has led to a study of the life-history of infective organisms outside of as well as in the animal body. The mode of propagation, the means of transmission of infective microörganism, by fomites and other agents, has become known. The rôle of insects which infect animals play, as definitive or intermediate hosts, has been studied and proved. The discovery of Manson of the transmission of Filaria sanguinis hominis by the mosquito was of vast importance as a suggestion of the mosquito as a definitive host in malaria. The investigations of Manson, Ross, Celli, Grassi, Dionise, Marchiafava, Bignami, Koch, and others have made our knowledge of malaria exact. With the microscope we may now not only recognize malaria and differentiate it from the other infective fevers, but we may also at the same time recognize by an examination of the blood the type of malarial infection and foretell its course. Not only may we recognize the disease definitely and apply the drug treatment more rationally, but the knowledge of the means of its transmission from man to man enables us to apply preventive measures which are of the greatest importance from a commercial as well as from a humanitarian point of view. The recognition of the rôle of the mosquito in malaria has been, furthermore, a stimulus to the study of the same insect in relation to other infections.

The brilliant research work of Reed and Carroll in 1900 in Cuba, by which they proved that the mosquito of the genus stegomya is the sole means of the transmission of yellow fever from man to man, is of great importance as a scientific fact. The influence of this discovery upon mankind, as a prophylactic against a disease which has killed multitudes, is wonderful.

Hardly less important is the fact that the Bacillus pestis may infect fleas and these in turn infect rats, mice, and man. It is important, too, to know that pests like the house-fly may be carriers of infective bacteria from refuse filth to kitchens and tables and contaminate food, and thus infect u swith typhoid fever, cholera, and perhaps other diseases which are propagated by filth.

The study of bacteria in the laboratory and in the blood tissues of infected animals has led to the discovery of the means by which bacteria disturb the animal economy and produce phenomena expressive of disease. The fact that the blood and tissues of infected animals contained a toxin which could also be isolated from pure bacterial cultures in the laboratory and that this toxin when introduced into an animal was capable of exciting the same phenomena of disease as the bacteria themselves, was positive proof that bacteria excite disease phenomena at least in some instances by means of a toxin which they form. The elaboration of antitoxins in the body of the infected animal was also promptly recognized, and served to explain not only the self-limitation of many of the infective diseases, but it also helped us to understand the immunity which one attack affords in some of the bacterial diseases.

Protective Inoculation

Long before bacterial toxins were recognized as the cause of disease phenomena, Pasteur established the principle of protective inoculation with bacteria of lessened virulence, which was brought about by attenuation of the bacteria by a modification of cultural methods and also by serial inoculation of certain lower animals. This he successfully applied to charbon in sheep and cattle and to chicken cholera. In both of these diseases the bacteria were known and the problems of attenuation could be carried on in the laboratory by direct study of the bacteria before inoculation and afterward when they were recovered from the body of the animals experimented upon.

His final life-work was no less important in firmly fixing the immunizing influence in rabies. Here the discovery was made that the infecting bacterium escaped every known means of recognition by microscopical and cultural examination of the tissues and blood of the infected animals. Apparently there are pathogenic germs which we do not know because we have not yet recognized the proper culture material for the successful artificial cultivation of them, nor have we discovered the tinctorial reaction which they may possess; and, finally, it is not improbable that they may be infinitely smaller than other germs and, therefore, more difficult to recognize.

Pasteur recognized the fact that in hydrophobia the brain and other nervous tissues of an infected animal are capable, when inoculated into another animal's brain, of producing the disease. That the infected brain used for infecting animals contained the germs which caused the disease was proved by the fact that a stage of incubation occurred in the inoculated animal and that a series of animals were successfully inoculated consecutively from the first. Pasteur then successfully attenuated the unknown microorganism present in the nervous tissues of an inoculated animal by dessication of the nervous tissue in a sterile apparatus by methods too well known to repeat. Nor is it necessary to occupy time in repeating the well-known methods pursued by Pasteur and his pupils in the use of the graduated doses of attenuated toxin contained in the nerve tissues in the prophylactic treatment of rabies. To Pasteur, therefore, we owe the scientific recognition of the principle of protective inoculation.

It is now a well-known fact, however, that inoculation against disease was practiced by the Chinese a thousand years ago. They inoculated the healthy with small-pox as a protection against the disease. Variolization was also practiced in Europe in the seventeenth and eighteenth centuries. We read that in 1718, Lady Montague caused a son to be inoculated with variola in Italy, and that two years later her daughter was inoculated in England. The practice was followed in Ireland long after the successful establishment of vaccine as a protection against variola. Inoculation against syphilis, or syphilization, was practiced in Europe during the nineteenth century.

We owe to Jenner, however, the first example of the protective inoculation by means of an attenuated virus. This attenuation we now know was established by the accidental inoculation of milch cows with small-pox, producing a modified disease, vaccinia. That vaccinia, produced in man by inoculation, would protect against small-pox was proved when, in 1798, Jenner successfully vaccinated direct from the cow, the five-year-old lad William Summers.

The thousands of successful vaccinations which have since been performed and the thousands of lives which have been saved by vaccination are proof of its validity and utility. The immunity established by protective inoculation is apparently the same as that induced by an unmodified attack of variola.

Serum Therapy

When chemistry had revealed the nature of bacterial poisons and experiments established their relation to the phenomena of disease, it was proved that substances were formed in artificial culture media and in the blood and tissues of infected animals which had the power to neutralize the effect of the bacterial poison in other animals infected with the same organism. Further investigation showed that an animal inoculated with the laboratory preparation of antitoxin was protected against the disease.

Furthermore, it was found that the blood serum of an animal inoculated with bacteria in a non-fatal and repeated dose contained an antitoxin. When the blood serum of an infected animal was injected into a healthy animal, the latter was protected against the original disease.

Antitoxin was, therefore, proved to be formed in artificial media of bacterial cultures and in the bodies of infected animals. When the antitoxin thus formed was injected into an animal, it had the power to protect that animal against the particular bacterial infection, or, if given subsequent to the infection of the animal, to mitigate the severity of the disease or entirely to check it.

Thus Koch and his students established the principle of serum therapy. Upon this principle there has been developed and given to the world the anti-diphtheritic serum of Behring and of Roux, and also an immunizing serum for Asiatic cholera, tetanus, erysipelas, plague, epidemic dysentery, streptococcus infection, and other diseases. While the serum treatment has not proved successful in all of the diseases in which it has been used, it has been so successful in some — diphtheria, for instance — as firmly to establish the principle of serum therapy. The study of prophylactic sera by Paul Erlich led to our present knowledge of immunity. His side chain theory has established a working basis which affords superb fields of research in physiologic chemistry which have already yielded rich returns.

Bacteriology made possible the comprehension of perfect cleanliness and enables the surgeon to invade every part of the body without fear of infection and has saved thousands of lives which twenty-five years ago would have perished miserably as the result of disease at that time inoperable, or as the result of infection from contact with the surgeon. By means of cleanliness and skill, induced by a broader experience, the surgeon has been able to add to our knowledge information of great value which could have been obtained probably in no other way. He has been able to study disease in the living body and show the relation of a disease process to infection. He has thus been able to clear away many of the misconceptions of symptomatology and diagnosis, especially in disease of the abdominal organs.

Bacteriology has stimulated laboratory clinical diagnosis. Bacterial reaction to sera and blood cultural tests are of the greatest aid to diagnosis. Clinical research work has command of an armamentarium consisting of a knowledge of pathologic anatomy, of physiology, of bacteriology, of chemic physiology, and of physics, which allows of a precision in diagnosis never before at the command of the physician.

The evolution of bacteriology has afforded a stimulus and aid in the advancement of parasitology, physiology, physio-chemistry, and of other fundamental sciences. This knowledge has been more directly applied to practical medicine than ever before.

Indeed modern medicine is now so comprehensive that the student must be thoroughly conversant with chemistry, inorganic, organic, and physical, with physiology, with general biology, with human and comparative anatomy, with bacteriology, and parasitology, to understand and appreciate it.

Slowly but surely the secrets of the cause of disease which baffled the search of centuries have yielded to the brilliant light of modern methods. The causative agents of most of the infective diseases of man and of the lower animals are now known.

The unknown causative germs of the few remaining infectious diseases will soon be discovered, and then the principles of immunity and cure by inoculation or by the application of antitoxins will find wider application.

Prevention of Infection

The recognition of the germ-cause of the infectious diseases enables modern medicine not only to combat disease more rationally and successfully, but it enables us to prevent them.

In most of the infective diseases due to germs, protozoa, parasites, and fungi, the causative agents have been so fully investigated that we know the life-history, and what conditions are best suited for the propagation and multiplication of each, and also what will remove and annihilate these dangerous enemies. So the diseases of domestic animals which may also infest man, for example, actinomycosis of cattle, trichina of swine, tuberculosis of animals, chicken cholera, foot and mouth disease, charbon, etc., may be entirely eradicated. The experience of one hundred years proves that smallpox may be prevented by proper vaccination. If universally applied and repeated at proper intervals the disease would probably disappear.

Our knowledge of the living agents which provoke malaria, typhoid fever, cholera, the plague, and the means by which they propagate, develop, and the manner in which they infest man, enables us, if we may command the situation irrespective of the financial cost, not only to prevent but also in many localities to abolish them altogether.

The discoveries of Reed, Carroll, and Agramonti of the relation of the mosquito (Stegomyia fasciata) to yellow fever has been practically applied with notable success in Cuba and elsewhere.

The study of bacteriology has developed general hygiene to a high plane. The value of sunlight, pure air, and pure food are fully recognized as preventives and also as rational curative measures in many infective diseases.

Unfortunately there are a few of the scourges of mankind which science has not yet conquered. Pneumonia, the bacterial cause of which is known, is still a "captain of death." Cancer remains unconquered. So, too, do many of the chronic diseases, namely, the primary blood diseases, diabetes, the various degenerative processes, etc., which, though frequently easily recognized during life, are at best only modified by our efforts to check or remove them.

Physio-chemistry, experimental medicine, physiology, and pathologic anatomy have given us much information of these processes, and there can be no question that many of these problems will be solved by the present methods of investigation.

The present knowledge of the cause of disease, of the evolution of disease processes, of the natural expression of disease as recognized by clinical investigation, has resulted in a rational mode of treatment. Drug treatment is no longer looked upon as specific, but as a helpful agent to modify and palliate disease processes, in conjunction with proper dietary, hydratic, and hygienic measures. Polypharmacy and indiscriminate drugging and drug nihilism are recognized as equally irrational. It requires a nice judgment of when to give, as much as when to withhold, drugs.

To enable a diseased or crippled organ more nearly to perform its function; to fortify and prolong life, with the hope of a favorable termination of a self-limited disease; to palliate suffering, are some of the measures which drugs afford modern medicine. Pharmacology and pharmacy have developed equally with the other parts of medicine and enable us to command drugs and active principles with accuracy and comfort.

The discovery of the X-ray was a boon tosurgical diagnosis and it has proved of wonderful therapeutic value in many of the disease processes of the skin and superficial tissues. When the X-ray shall be better understood its appreciation will be undoubtedly much more extensive.

The rapid development of modern medicine has attracted wide attention and excited the interest of students and investigators over the whole world.

A larger percentage than ever before of the best-educated students of the world have sought medicine as the most attractive field of study and research. At this time there are hundreds of earnest, thoughtful, patient, and energetic workers after truth who frequently sacrifice home, friends, comfort, health, and even life for the advancement of the science of medicine.

The advancement of modern medicine has also attracted the attention of the philanthropic rich as never before. In recent years institutes of research have been erected or are in the course of construction and equipment which have rich endowment. Modern medicine is therefore better prepared to develop now than ever before.

The development of medical literature has been in keeping with the advancement of other sciences. Large and valuable libraries are found in every land. Medical journalism is a science of itself and enables the physician at small cost to be in touch with all that is new and progressive.

Modern medicine requires of its students an education which shall fit them to take part as research workers or as practitioners to apply the measures afforded them to prevent or more quickly to modify disease. The modern medical student, therefore, requires the broad education of the university and a training of his special senses in the study of the natural and of the fundamental medical sciences, preliminary to the study of applied medicine and surgery. Happily both the old and the new world afford institutions which satisfy all requirements of modern medical education. Many medical institutions exist which cannot furnish the necessary educational advantages. These institutions are doomed. They are relics of the past. It is to be hoped that they will be no exception to the rule of the survival of the fittest.

SECTION A—PUBLIC HEALTH

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(*Hall* 13, *September* 21, 10 *a. m.*)

CHAIRMAN: DR. WALTER WYMAN, Surgeon-General of the U. S. Public Health and Marine Hospital Service.
SPEAKERS: PROFESSOR WILLIAM T. SEDGWICK, Massachusetts Institute of Technology.
DR. ERNST J. LEDERLE, Former Commissioner of Health, New York City.
SECRETARY: DR. H. M. BRACKEN, St. Paul, Minn.

DR. WALTER WYMAN, Surgeon-General of the United States Public Health and Marine Hospital Service, and Chairman of the Section of Public Health, in calling the Section to order, expressed his appreciation of the honor that had been conferred upon him in being made the presiding officer of so important a section, and congratulated the members of the Congress who were present on taking part in a congress so unique in history, so distinguished in membership, and whose proceedings would doubtless prove of such great value to mankind.

Recent legislation (Act of July 1, 1902) had provided for the United States a body practically fulfilling the requirements of a national board of health under the name of Public Health and Marine Hospital Service, an evolution from the century-old Marine Hospital Service. The Service controlled a laboratory for the investigation of infectious diseases and matters relating to the public health, its medical corps comprised between three hundred and four hundred medical officers, distributed throughout the United States and also representing the Service in foreign lands in sanitary matters.

The difficulty had been hitherto to establish a national health organization in which there might be a representation of the states without weakening the administrative and executive force of the national service and giving the states a voice in at least the consideration of matters pertaining to the public health. This had been brought about by the provision for annual conferences between the state and national health authorities.

One difficulty which has always faced Congress in the establishment of a national health organization was not to assume extra, constitutional rights. The power of Congress in matters pertaining to epidemic disease and matters relating to public health lie chiefly in its power to regulate commerce, though doubtless many would believe that under the public welfare clause of the Constitution certain beneficent institutions could be organized and maintained by the national government. As a matter of policy, the attitude of Congress is also in accord with the spirit of the Constitution. It has not been deemed desirable that the United States Government should be too paternal, but should leave most of the details in public health matters to the state and municipal governments. Occasionally there is a tendency toward a weak leaning on the national government, which should not be encouraged, but in the opinion of the Chairman it is the wisest policy at present that the national government should only give aid when it is necessary to do so in the interest of several states or communities combined. The leaving of ordinary public health matters to the management of the state health boards would strengthen them in their organization and in their appeals to the state legislatures for appropriations. Any national system must necessarily include, for its efficacy, the health organizations of the several states and their development in power.

Time may develop a closer relation between the national and state, or local, governments with regard to local sanitation, since the latter is closely connected with epidemic diseases which become the care of the national authorities.

Through the Hygienic Laboratory, with its advisory board, the scientific work of the Public Health and Marine Hospital Service is brought into contact with the scientific laboratories of the country. Through the conferences with the state health officials the practical administrative work of the Bureau and its various sanitary problems are now considered in conjunction with the official representatives of the state governments; and a good scientific and executive framework of the national health structure exists in the corps of specially trained medical officers, under military discipline, and trained in government methods.

The national health organization, as thus outlined to-day, is much stronger than was the old national board of health, but it should be stated that while the organization seems to have sufficient scope, much remains to be done to perfect the details.

THE RELATIONS OF PUBLIC HEALTH SCIENCE TO OTHER SCIENCES

BY WILLIAM THOMPSON SEDGWICK

[**William Thompson Sedgwick,** Professor of Biology, Massachusetts Institute of Technology. b. West Hartford, Connecticut, December 29, 1855. Ph.B. Sheffield Scientific School, 1877; Ph.D. Johns Hopkins University, 1881; Fellow, *ibid.* 1879–80. Instructor in Physiological Chemistry, Sheffield Scientific School, 1878–79; Instructor and Associate in Biology, Johns Hopkins, 1880–83; Assistant Professor, Associate Professor, and Professor in Biology, Massachusetts Institute of Technology, 1883; Biologist of Massachusetts State Board of Health, 1888–96; Curator of Lowell Institute, Boston, 1879. Member of American Association for the Advancement of Science, Society of American Bacteriologists, American Public Health Associations, American Society of Naturalists, American Academy of Arts and Sciences. **Author of** *General Biology* (joint author); *Life and Letters of William Barton Rogers* (assistant editor); *Principles of Sanitary Science and Public Health; The Human Mechanism* (joint author).]

"Physical science is one and indivisible. Although for practical purposes, it is convenient to mark it out into the primary regions of physics, chemistry, and biology, and to subdivide these into subordinate provinces, yet the method of investigation and the ultimate object of the physical inquirer are everywhere the same." — HUXLEY.

PHYSICAL SCIENCE is one and indivisible; that, as I understand it, is the keynote of this great Congress, of which public health science forms one section, and as I am invited to consider, in the brief space of forty-five minutes, the relations of public health science to other sciences, I shall take the liberty of selecting from the whole number of "other sciences" only a few, the relations of which to public health science seem to me for one reason or another especially important at the present time. I accept the term public health science without hesitation, for any division of human knowledge which has worked out its own laws with strict adherence to the rules of inductive and deductive reasoning, as public health science has done, and which has reached results enabling it to predict with accuracy, as public health science can now predict, is entitled to a place and an honorable place among the physical sciences.

Public health science had its rise and a considerable development in the eighteenth century. Before that time numerous procedures tending to protect or promote the public health had, indeed, at one time or another existed, but these were largely empirical and quite as often directed to the convenience of mankind as to their sanitary safety. In this class belong the Mosaic code; the water-supply introduced into Jerusalem by Hezekiah; the sanitary engineering of Empedocles; the *Cloaca Maxima;* the water-supplies of ancient Mycenae and of Rome, and all the earlier, and too often futile, forms of quarantine. Even the art of inoculation for small-pox was only an ingenious knack introduced from the East, where it had been long used empirically, and although it was a public health measure now of the utmost interest and capable at the time of great practical service, it had until recently no scientific basis, but belonged in nearly the same class as the amulets and charms, the prayers and incantations, of the superstitious.

It was not until the middle of the eighteenth century, namely, in 1767, that Sir George Baker, by the use of the methods of pure inductive reasoning, made the first scientific discovery in public health science in the subdivision of epidemiology, namely, that the epidemic cholic of Devonshire, England, was due to an obscure poisoning by lead conveyed through the common cider used for drinking in that district. In 1774, the foundations of state hygiene and sanitation were laid in consequence of the patient investigations and startling revelations of John Howard, by an act of Parliament providing for the sanitation of jails and prisons. The beginnings of marine hygiene and sanitation appear in 1776, when Captain Cook, the navigator, was awarded the Copley Medal of the Royal Society for his remarkable success in protecting the lives of his sailors on his second voyage. In 1796, Edward Jenner, working also in a strictly scientific manner, and employing the methods of rigid inductive research, laid securely for all time the foundations of personal hygiene and immunization, by showing how we can produce at will such modifications of the physiological resistance or susceptibility of the human body as to make it immune to small-pox.

The importance of these fundamental and splendid discoveries, not only to the public health of the time, but far more to the development of public health science in all the centuries to come, is incalculable. Reduced to their lowest terms, we have in these eighteenth century discoveries the germs of some of the most important divisions of public health science as it is to-day, namely, (1) *epidemiology*, (2) *sanitation of the environment*, and (3) *immunization of the human mechanism*, this last the most marvelous phenomenon hitherto discovered in personal hygiene.

Time fails me to do more than name some of the principal steps in the advancement of public health science in the nineteenth century. We have, for example, in 1802, the beginnings of factory hygiene and sanitation; in 1829, the first municipal water-filter, one acre in area, constructed for the Chelsea Company of London; in 1834, recognition of the important relation of poverty to public health, in the famous report of the Poor Law Commissioners of that year; in 1839, the beginnings of registration and accurate vital statistics; in 1842, an important report on the sanitary condition of the laboring population of England; and in 1843, a similar report on the health of towns; in 1854, for the first time clearly taught, the lesson, even yet not properly taken to heart, that drinking-water may be the ready vehicle of a terrible epidemic of cholera. About 1860, striking epidemics of trichinosis first came into public notice, and here, also, belongs the magnificent work of Pasteur, while in 1868, Lister, following in the footsteps of Pasteur, revealed to the world the basis of true cleanliness in asepsis, and in 1876, bacteriology became firmly established as a science by Koch's studies on anthrax. The decade from 1880 to 1890 may be called the golden age of etiology, for in these years were discovered the hitherto unknown parasitic microbes of typhoid fever, tuberculosis, malaria, Asiatic cholera, diphtheria, and tetanus. The last decade of a century which has well been called "the wonderful," witnessed the discovery of antitoxins by Behring and the beginnings of serum therapy. The list is long, and I have not mentioned nearly all of the discoveries of capital importance, but because of these and their fruits, I am in the habit of saying to my students that with the single exception of the changes effected by the acceptance of the theory of organic evolution, there has been no modification of human opinion within the nineteenth century more wonderful, or more profoundly affecting the general conduct of human life, than that in our attitude toward the nature, the causation, and the prevention of disease — that is to say, toward public health science.

No mere outline like this of the history of public health science can possibly serve to show how, like other applied sciences, this one has not grown as a branch grows from a tree, namely, from a large stem or stock of knowledge, tapering out into thin air, and with its latest growth its least and weakest. That common simile, in which the various divisions of science are represented as branches of the tree of knowledge, is a grotesque survival of a time when neither trees nor science were understood. No simile is perfect or even approximately correct, but one better than the tree and its branches for the origin and relationships of any inductive science is that of a river, rising from various and often obscure sources, growing in size and importance as it proceeds both from the springs within its own bed and by the entrance and contributions of tributary streams, and finally pouring its substance into the mighty ocean of accumulated human knowledge.

Up to the time of the establishment of the registration of vital statistics in England, in 1839, the stream of public health science, although full of promise, was only a slender thread, but when the results of registration were fully enlisted in its service it visibly widened and deepened. Epidemiology, as has been said, had the honor of giving birth to the science in 1767, and it added to its offspring a rich endowment when, in 1854, Dr. John Snow proved that the water of the Broad Street well in London had caused an epidemic in which more than six hundred persons died of Asiatic cholera. The stream of public health science was still further enlarged and quickened by the revelation in and after the sixties of the simple causes of numerous epidemics of trichinosis and of typhoid fever, the latter sometimes through milk. There was an extraordinary popular awakening in England to the importance of sanitation and public health measures in the middle of the nineteenth century, but we look for some time in vain for any marked inosculation between public health science and other sciences, such as physics, chemistry, microscopy, bacteriology, climatology, engineering, or education. We have, to be sure, minor contributions from the microscopists, such, for example, as that from Dr. Hassall, who, in 1850, made a careful microscopical examination of the water-supply of London and showed the presence in the public drinking-water of muscle fibers, intestinal parasites, and other materials, plainly derived from sewage; but it was not until Pettenkofer and his disciples, in Germany, and Angus Smith and others, in England, began their splendid chemical investigation that the tributary stream of *sanitary chemistry* enlarged materially that of public health science. In saying this I do not forget that my late friend and colleague, William Ripley Nichols, whose solid contributions to sanitary chemistry were among the first in America, and will always remain among the best anywhere, long ago pointed out that, as early as 1789, "Fourcroy studied the nature of 'litharged' wine, Berthollet (1801) the methods of preserving water for long voyages, Chevreul (1846) various chemical reactions which explain the hygiene of populous cities, and (1856, 1862, 1870) methods of preparing and preserving food; Graham and Hofmann reported upon the use of acetate of lead in sugar-refining (1850), upon the London water-supply (1851), and upon the adulteration of pale ales with strychnine (1882); Dumas was interested in many sanitary matters and made, among others, reports on the mineral waters of France (1851), on the water-supply of Paris (1859), on the treatment of sewage (1867), and on the preservation of food (1870–72); Wurtz was for a number of years president of the *Comité consultatif d'hygiène* and a year before his death was president of the *Société de médecine publique*. His investigations and reports on sanitary subjects are numerous — on the disposal of the waste from distilleries and sugar-refineries, on the colors employed on German toys and in articles of food, on the adulteration of wines, etc.

"Other names will occur to us — such as those of Sir Henry Roscoe, Sir Frederick Abel, and Dr. Williamson, who served on the Noxious Vapors Commission of 1876; of Frankland, who gave years of service to the Rivers Pollution Commission of 1868 and in connection therewith devised an elaborate system of water analysis; we think also of Schutzenberger devising a method for the determination of oxygen dissolved in water (not, to be sure, simply for sanitary purposes), Mallet studying the various methods of water analysis, Remsen studying the organic matter in the air, and Leeds the practical effect of charging with oxygen (or rather with air) water used for purposes of domestic supply."[1]

I dwell intentionally upon the service of sanitary chemistry to public health science previous to the rise of bacteriology, because I believe that, dazzled as we have been and still are by the blazing achievements of bacteriology, beginning, let us say, with the discovery of the microbe of tuberculosis by Koch in 1882, students of public health science have been too much inclined to underrate the past services and present relative importance of sanitary chemistry. I know of few more important contributions to public health science, even since 1882, than the chemical work of the State Board of Health of Massachusetts under the able direction of my friend, Professor, afterwards President, Drown (the successor of Nichols) and his associates and successors; or that of another friend, the late Professor Palmer, of the University of Illinois, whose chemical studies of the rivers of Illinois will long remain a monument to a life full of promise and too soon cut short; or that of still another friend, Professor Kinnicutt, who fortunately is still engaged in fruitful work.

I have perhaps said enough, though it would be difficult to say too much, of the magnificent contributions to public health science of Pettenkofer and his disciples in sanitary chemistry; but the work of these investigators in *sanitary physics* and especially the physics of the soil, of the atmosphere, of the walls of buildings, and of heating and ventilation, in their relations to the public health are quite as important, and perhaps to-day even more neglected. In view of the increased facilities of transportation and the growing habit of traveling, together with the tendency to outdoor life, which seem to be characteristic to-day of all civilized nations, the next twenty-five years will probably see a return to the patient and exact studies of *the environment*, such as the chemists and physicists began, and have in some measure continued, since the middle of the nineteenth century. These studies will be directed largely to further knowledge and control of the environment, but they will not end there, for *personal hygiene*, owing to recent advances in physiology, is to-day one of the most inviting fields for work and education, and I hardly need to point out to a company of experts that the proper care and right use of the individual human mechanism reacts favorably and fundamentally upon the public health no less truly or effectively than an improved condition of the environment or of the public health tends to promote the welfare and long life of the individual.

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[1] William Ripley Nichols, address before American Association for the Advancement of Science, *Proceedings*, American Association for the Advancement of Science, vol. XXXIV, 1885.

The sphere of hygiene may be divided, as it often is, into the two hemispheres, public hygiene and personal hygiene, or it may be cut into one portion dealing chiefly with the human mechanism and its operation (*personal hygiene*), and another portion dealing chiefly with the environment of that mechanism (*sanitation*). The time has gone by when any one person can safely undertake to deal with the whole sphere of hygiene. The physiologist and the physician must in the future leave to the architect and the sanitary engineer such subjects as housing, heating and ventilation, water-supply and sewerage, precisely as the sanitary engineer has never presumed to deal with foods and feeding, vaccines and antitoxins, exercise, sleep, and rest. The former subjects deal chiefly with the control of the environment, the latter subjects chiefly with the control of the individual, and sanitation and hygiene must henceforward be regarded as separate hemispheres of the science of health.

The *science of architecture*, if under this head we include the principles of building construction, and the heating and ventilation of buildings, has done and is doing much of interest and importance to the student of public health science. For my own part, I am continually more and more impressed with the fact that the air-supply, especially for the modern civilized and too often sedentary form of mankind, is in the long run quite as important as the water-supply, the milk-supply, or any other supply. Surely, we cannot be too careful of the purity of a substance which we take into our bodies oftener, and in larger volume, than any other, and which has come, rightly, no doubt, and as the result of long and painful experience, to be known as the very breath of life. I am well aware that human beings may survive and seemingly thrive, even for long periods, in bad air, but I am certain that for the best work, the highest efficiency, the greatest happiness, and the largest life, as well as for perfect health, the very best atmosphere is none too good. Hence I believe that the permeability of the walls of houses and other buildings, and the heating and ventilation of dwellings, school-houses, churches, halls, and other public places, require, and in the near future will receive, a much larger share of our attention than they have to-day.

In an age characterized by urban life and possessing sky-scrapers, tenement-houses, and other huge beehives, in which human beings aggregating vast numbers spend a large part of their lives, buildings require for their proper construction, lighting, heating, air-supply, water-supply, gas-supply, and drainage, the scientific services not only of architects, but of engineers, and such public buildings form one small section of the aid which modern *engineering science* is now everywhere rendering to public health science. The present has rightly been called an "age of engineering," and to no other science, excepting only medicine itself, is public health science to-day more indebted than to engineering science. I have referred above to the construction of the first municipal filter attached to a public water-supply as that of the Chelsea Company of London, constructed in 1829. How different is it to-day! Not only nearly the whole of London, but also Berlin and Hamburg, and a thousand lesser cities all over the civilized world, are now protected more or less perfectly from epidemics of typhoid fever, Asiatic cholera, and other water-born diseases, by vast municipal filters, ingenious and scientific in design and costly in construction, the work of skillful and faithful engineers, and monuments more precious if less enduring than brass to the contributions of engineering science to public health science. Innumerable storage reservoirs and vast distribution systems for supplies of pure water also bear witness to the enormous debt which public health science owes to engineering science, as do proper street construction and, still more, those splendid systems of sewerage with which so many modern cities are equipped, and which not only serve to remove quickly dangerous liquid waste of human and animal life, but also keep low and wholesome the level of the ground-water, reducing dampness and promoting dryness of the environment, and thereby strengthening that physiological resistance by means of which the human mechanism fights against the attacks of infectious disease. Nor do the services of engineering science end here, for the fluid content of the sewers must always be safely disposed of, and sewage purification is to-day a problem of engineering science no less important or difficult than that of water purification. These same processes of the purification of water and sewage are matters of so much moment in public health science that in almost every country experiment stations are now maintained at public and private expense for the purpose of working-out the most practical and most scientific methods of purification.

In no respect have the services of engineering science to public health science been more conspicuous than in the application and the further study of the principles involved in the processes of water purification. It has lately been shown, for example, that the introduction of pure water-supplies has in many cases so conspicuously lowered the general death-rate as to make it impossible to escape the conclusions (1) that the germs of a greater number of infectious diseases than was formerly supposed are capable of prolonged life in, and ready conveyance by, public water-supplies, and (2) as a promising possibility, that as the result of the greater purity of the water-supply the physiological resistance of the consumers of pure water-supplies is enhanced, in some manner as yet unknown; the net result being that the general death-rate is lowered to such an extent as to lead to a rapid increase of population in communities previously stationary or multiplying far less rapidly. In the case of the city of Lawrence, Massachusetts, for example, I have recently had the privilege of examining the results of studies by the distinguished hydraulic and sanitary engineer, Mr. Hiram F. Mills, which show that since the introduction of a municipal filter, which purifies the water of the Merrimac River supplying water to the citizens of Lawrence, while the population has increased nearly seventy per cent, the total number of deaths remains about the same as it was ten years ago. Mr. Mills concludes from the results of his studies — and I see no escape from his conclusions — that the introduction of the municipal filter has not only saved the lives of thousands of citizens, but has also caused the population to increase to a point much beyond any which it would have reached had the city continued to use, unpurified, the sewage-polluted water of the Merrimac River. A demonstration of this sort shows how easily the diminishing increase of population under a lower birth-rate may sometimes be counteracted without resort to that fish-like spawning which seems to be the only remedy of those who are terrified by "race suicide," so called. Moreover, it is hardly necessary to point out that such a diminishing death-rate means a far more rapidly diminishing morbidity rate — in other words, it means a heightened working efficiency of the population as a whole, and it must not be forgotten that for most of the results obtained in the scientific purification of water-supplies we are indebted to the science of engineering.

On the other hand, we must observe that engineering science, so far as water purification is concerned, is as yet only in its infancy and by no means thus far altogether satisfactory. In the United States, for example, in the last two or three years a number of epidemics of typhoid fever have resulted from the *defective operation or construction* of municipal filters, and while much has been done, it is clear that much still remains to do. In this connection it should be said that public health science in the United States suffers constantly and severely from an unsatisfactory condition of the science and art of administration or government in many American cities. Public health works are too often neglected, delayed, mismanaged, or built at extravagant cost, to the sanitary and economic damage of the people as a whole, and the tendency is far too common to place the care and operation of costly devices or systems in incompetent hands. I cannot here dwell, as long as I should like to do, upon the mutual relations of public health science and the sciences of legislation and administration. Speaking of my own country alone, I must confess that we are still very deficient in the applications of these sciences. We have not even a national board of health, although we have, fortunately, in the Public Health and Marine Hospital Service a strong substitute for one. The peculiarities of our democratic and republican government have hitherto made it impossible for the people of the United States to secure either from federal authorities or from more local sources that measure of paternal sanitary and hygienic protection which they ought to have, and it is the duty of every American worker in this field to bend his energies toward a better organization of the public health service in every direction, municipal and state as well as national. The appointment in 1886 of a distinguished hydraulic engineer to membership on the State Board of Health in Massachusetts marked an epoch, so far as America is concerned, in both sanitary legislation and administration. This appointment was a formal recognition on the part of the public of the necessity of a larger proportion of engineering science in matters relating to the public health, and the results have justified the new procedure. It is now, fortunately, becoming less rare in America to secure the services of engineers upon such boards, and there can be no question that participation of the expert laity with medical men is likely to be extended, probably far beyond our present ideas.

In a notable discourse before the International Medical Congress at the Centennial Exposition held at Philadelphia in 1876, Dr. Henry P. Bowditch, of Boston, one of the pioneers of hygiene and sanitation in America, divided the century then closing, as to its relation to public health science, into three periods, the first, from 1776 to 1832, a period of reliance upon authority and upon drugs; the second, from 1832 to 1869, a period of true scientific observation; the third, from 1869 onwards, an epoch in which the medical profession is aided by the laity and state hygiene is inaugurated. Dr. Bowditch has much to say of the desirability of a wider coöperation of the laity in state hygiene and remarks: "In all that tends to the promotion of state hygiene hereafter the laity will naturally and cordially coöperate with the [medical] profession." The history of public health science shows Dr. Bowditch's prediction to have been well grounded. The names of John Howard and Captain Cook in the eighteenth century, and of Edwin Chadwick, John Simon, and Louis Pasteur (not to mention a host of lesser workers) in the nineteenth century, show conclusively that public health science has been, even from the start, by no means confined to medical men. We may go further and say that even when forwarded by medical men these have seldom been busy practitioners. Sir George Baker and Jenner were, it is true, of this class, but not Pettenkofer, or Koch, or Ross, or Billings, or Reed.[1]

Reflections of this sort naturally lead to a consideration of the reciprocal relations of public health science and the science of education. I do not need to dwell upon the beneficial effects of public health science upon the hygiene and sanitation of school-children or school-houses. These benefits have long been emphasized by sanitarians and sanitary reformers and are sufficiently obvious. The reverse of the picture, however, is by no means so well understood. Unless one is familiar with the facts, it is difficult to conceive how little impression the splendid progress which the last fifty years have witnessed in public health science has as yet made upon the curriculum of education. From top to bottom and from bottom to top the schools, whether primary, grammar, high, normal, technical, medical, or any other class, are recreant, inasmuch as they neglect almost wholly any adequate training of their pupils in the principles of public health science which are confessedly of such profound importance to mankind. There is, to be sure, just now a popular wave of enthusiasm touching the extermination of tuberculosis, but in the United States, at any rate, both schools and universities are singularly negligent of their most elementary duties in this direction. Yet if what I have said before is true, if the laity are to participate from this time forward with medical men in sanitary and hygienic legislation and administration, if engineers and medical men in particular are to serve upon boards of health or in other executive positions connected with public works, then, surely, it is the duty of the science of education to lend its powerful aid and not to fail to save the lives and health of the people as these can be saved to-day, but always to promote that public health and that large measure of consequent happiness which can probably be more easily and quickly accomplished in this way than in any other.

As to the function of medical education and engineering education in respect to the dissemination of public health science, I shall say only a word. In spite of the reiteration by medical men of their belief in the importance of hygiene and preventive medicine as a part of the equipment of the medical profession, it is a significant fact that in America even the best medical schools devote very little time to any adequate instruction in these subjects. It may be that this is wise and that the pressing necessities of practical medicine forbid any extended instruction in public health science. I am willing to believe, if I must, that this may be the case; but if it is, then the community must look for the most part elsewhere than to medical men for adequate investigation, legislation, and administration of public health science. Medical men, must, of course, always participate in the work, in connection, particularly, with the control of epidemics and in those forms of preventive medicine which have to do with vaccines, serums, and other means of modifying the vital resistance of the human body. But as regards the care and control of the environment, medical knowledge is not indispensable, and the entrance of the engineer and the sanitary expert upon the field, as foretold by Dr. Bowditch nearly twenty years ago, is to-day a conspicuous, and probably a wholesome, fact. As to the attitude of engineering education toward public health science there can be no question. If what I have said before is true, then engineers are bound in the future to take constantly a larger and more important part in public health work, and must be informed, and if possible trained, accordingly. Moreover, as regards both medicine and engineering, the problem is by no means insoluble, for a very short course of instruction rightly given would easily inculcate the necessary fundamental principles, while electives or post-graduate work might enable those few whose tastes led them in this direction to investigate and specialize and more thoroughly prepare themselves for public service.

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[1] "During the course of an epidemic, physicians are too busy to make observations which require much time or care, or to make more than brief notes." — *J. S. Billings.*

I cannot treat, nor do I need to treat, as thoroughly as I would be glad to do, the mutual relations existing between medical science, especially the science of medical bacteriology, and public health science. These are already sufficiently obvious and well known. From time immemorial medical men have served, often devotedly and sometimes heroically, in the cause of public health science. I take it, however, that since we have in this Congress and in our own department a section of preventive medicine, I may pass over without comment this part of my subject.

As regards sanitary bacteriology, however, the relations existing between this and public health science are so fundamental, so extensive, and so important, not only on the medical, but also on the engineering side, that although we have also in this Congress under the department of biology, as is entirely proper, a section of bacteriology, I may linger at this point for one moment. The bacteria and other microscopic forms of plant and animal life, all of which are conveniently included under the term microbes, have so lately begun to be understood and appreciated that we must still emphasize their extreme importance. The discoveries of the botanists and zoölogists and revelations of the microscopists in this domain are comparable, in their importance to public health science, with nothing less than the revelations of the telescope to astronomy. Astronomy had, indeed, existed long before the invention of the telescope, and public health science, as we have shown above, had its beginnings nearly a century before any considerable progress had been made in micro-biology. But it is not too much to say that the developments in micro-biology since Pasteur began his work have not only revolutionized our ideas of the nature of the infectious diseases, but have also placed in our hands the key of their complete control.

Concerning the relations of *physiology* to public health science, I must not fail to speak. Here is a field absolutely ripe for the harvest, but one in which the harvesters are as yet very few. I have lately had occasion to examine somewhat carefully the present condition of our knowledge of personal hygiene — which is nothing more (and should be nothing less) than the applications of physiological science to the conduct of human life — with the result that I have been greatly impressed with its vast possibilities and promise. Man is a gregarious animal, and mankind is to-day crowding into cities as perhaps never before. Moreover, the industrial and commercial age in which we live is characterized to an extraordinary degree by the sedentary life. Yet the sedentary life is almost unavoidably an abnormal life, or at least it is a life very different from that lived by most of our ancestors. In the sedentary life the maintenance of a high degree of physiological resistance apparently becomes difficult, and if the vital resistance of the community in general is lowered, then the public health is directly and unfavorably affected, so that considerations of personal hygiene have a direct bearing upon the science of public health.

There are, to be sure, interesting and suggestive symptoms of a wholesome reaction, in America at any rate, against the evils of the sedentary life. Parks and open spaces are being liberally provided; public and private gymnasiums are rapidly coming into being; public playgrounds are thrown open in many of our cities, free of expense to the laboring, but, nevertheless, often sedentary, population; vacations are more than ever the fashion; sports and games are everywhere receiving increasing attention; while public baths and other devices for the promotion of personal hygiene are more and more coming into being. All this is as it should be, but all is as yet only a beginning. Here, again, the science of education is sadly at fault and in the direction of educational reform as regards personal hygiene lies immense opportunity for a contribution to public health science.

The science of *statistics*, which has done great service in public health science in the past, is likely to do much more in the future. Without accurate statistics of population, mortality, and the causes of sickness and death, the science of epidemiology is impotent, and the efficiency or inefficiency of public health measures cannot be determined. And yet in ignorant hands statistics may be worse than useless. It is a matter for congratulation to Americans that we now have in Washington a census bureau permanently established and under expert supervision, but until the various states and cities of the United States follow this excellent example of their Federal Government, one of the most important aids to public health science will continue to be wanting, as is unfortunately too often the case to-day not only in America, but in many other parts of the civilized world.

PUBLIC HEALTH: ITS PRESENT PROBLEMS

BY ERNST J. LEDERLE

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In expressing my thanks for the honor which the organizers of this Congress have done me in the assignment to speak upon the subject of "Public Health: its Present Problems," I find two reasons for so doing. The sense of personal gratification of course enters into my acknowledgment, for it is a pleasure to feel that one's efforts for sanitary reform, however slight in comparison with those of many who will address you, are appreciated beyond the limits of the city where those efforts were put forth.

It is an inspiration to the worker to find that whatever is of value in his work is eagerly observed, taken up, and adapted to conditions as they are found in other parts of our country. Perhaps the most interesting and valuable recollection I have of my work in the sanitary service of New York City is that, in the course of that work, I was able to gain from my co-workers in other cities fully as many ideas for sanitary betterment as we in New York could give. The effect of such coöperation is to make one realize that sanitary reform work is not local, not even national, but world-wide; and that every worker in its cause may draw at will upon the resources of his fellows while he gives them of his own.

But the personal pleasure I feel in speaking on this topic is subordinated to another consideration. The fact that it should have been assigned to any but a physician seems to me to be of much significance.

Sanitary science has been, for so much of its brief existence, set forth almost wholly by medical men, that it is still widely regarded as their peculiar province. And properly so; the very nature of his training and occupation makes the intelligent physician find in unsanitary surroundings a predisposing cause of disease; and his work has been and will continue to be so to improve sanitary conditions as to minimize and finally to eradicate a great many diseases which still make up a large part of the annual mortality.

Preventive medicine is the watchword of the new school. It is a sign of the progressiveness of that school that, in all enlightened communities, it has now realized the great scope of the preventive work to be done, and has called into existence a new profession, that of the sanitarian, in order to have the aid of specialists in hygiene in solving the problems of disease.

Modern public hygiene, in fact, has passed the point where the overcrowding of population has made prompt solution of sanitary problems imperative, there are many questions of administration and policy to be solved, and for these the physician ordinarily has little aptitude. His experience and training are rarely, if ever, of the sort to make him a successful administrator. I do not by any means seek to maintain that this function resides wholly in the sanitarian, so called; far from it. But in the adaptation of means to ends, in the countless circumstances of administrative duty which public service entails, a layman, with skilled medical advice upon purely medical questions, seems to me better fitted to accomplish results than the physician alone.

This leads me to a statement of what I believe to be the best possible organization of a sanitary service, municipal, state, or national, and one which I hope some day will be adopted not only in cities and states, but by our Federal Government. At its head should be a board of administration, consisting of a physician of the first rank, skilled in the application of bacteriological and general medical research to the problems of hygiene; a trained sanitary engineer; and third, if you like, as a balance-wheel to prevent the eccentrics of the specialists from disturbing the workings of the machine, a man of affairs in the broader sense of the word, who should be versed in sanitary practice and, at the same time, chosen mainly for administrative skill and for a certain practical common sense which might guide such an organization wisely, and, perchance, prevent misuse of the great powers with which it ought to be endowed. In the service of such a department of our government, there should be a staff of specialists in every branch of medical and sanitary science, laboratories equipped for research and diagnosis, and all other adjuncts which make for efficiency in public hygiene. One may question how such a body would be regarded by the existing sanitary authorities of cities and states; but, to my mind, it would be entirely feasible to coördinate all the minor divisions of sanitary service into one comprehensive whole, in which the central body, though maintaining its position of leadership, should exercise police powers with extreme caution while developing its advisory function to a degree of usefulness beyond any yet attained.

Those who see in such a plan an unwarranted extension of federal power might profitably study the workings of such organizations as the Kaiserliches Gesundheitsamt in Germany and the union of British medical officers of health. Particularly in the former are the beneficial effects of centralized authority evident. Our own government's centralized activity along such lines as that pursued by the Department of Agriculture is proving its value as an educational factor to our population beyond all question.

There seems to be no good reason why a similar organization for sanitary work should not be instituted. Its beginnings are to be found in the work of the Bureau of Animal Industry of the Department of Agriculture, which has already demonstrated its efficiency in enforcing interstate quarantine upon infected cattle, as well as in other ways too numerous to mention. Another governmental effort, conceived in the same scientific spirit, is to be seen in the founding of various state agricultural experiment stations, which are practically chemical laboratories working upon problems which the farmer, without scientific aid, might never be able to solve.

Federal establishments like these, for the study of hygienic problems and the betterment of health in sections of the country where such betterment is sorely needed, would have an immense educational value, besides conducting great works of sanitation on broad lines where now such work is either entirely neglected, or allowed, for the most part, to fall between the two stools of municipal and state sanitary authorities. Such a central body would also solve the vexed questions of national quarantine, which are now left to the varying judgment of local health officers in our seacoast cities, at times undoubtedly to the menace of the public health of the United States.

Another field of usefulness for a national board of health would be the training of sanitary officers. Sanitary science is so new, and the public appreciation of its benefits still so small, that the rewards for the pursuit of it as a life occupation are not sufficient to induce enough good men to make it a study. The result has been, thus far, that the men who do the actual work of sanitary inspection, even in the service of well-organized bureaus of health in the large cities, are as a class without other training than that which experience and, at best, a little reading on sanitation can give them. They may have been plumbers or carpenters before entering public service, but none of these bring any great amount of theoretical knowledge to their work. A few, of course, have been educated as physicians, but have turned to the sanitary field for one or another reason; often, perhaps, it is to be feared, because the certain small salary in the public service is more satisfactory than the doubtful rewards of more or less unsuccessful medical practice.

Some time ago, seeing the need for attracting to the pursuit of sanitation men of higher grade than the majority now engaged in it, I suggested to the president of one of our largest universities the plan of offering courses in hygiene and sanitation as part of the curriculum. He replied that the experiment had been tried, but that few or no pupils presented themselves; he thought that young men inclined to pursuits of this character chose rather the courses which would fit them for engineering, civil or mechanical, and he therefore advised that studies of this character might more profitably be offered through the medium of night schools and the like.

This was evidence to me that young men of the class which can afford a university education aimed at higher pecuniary rewards than are now afforded to workers in hygiene; it was also evidence that wider efforts should be made to demonstrate the great public need of educated sanitary officers, and the great opportunity the practice of hygiene affords for valuable public service. I believe that, in time, we shall have in this country a class of educated public sanitarians; but that time will not come until scientific work of this character is adequately paid for, and it will come sooner if the sanitary bodies in various states and cities, now working along independent and often conflicting lines, are coördinated and made a part of the greater activities of a national board of health, deriving its powers as do other main branches of the Federal Government.

To define the present problems of a modern board of health is to classify and describe its multifarious activities. Broadly speaking, of course, its main objects are to prevent the spread of contagious disease, and to enforce sanitary ordinances; but to these have been added, some may say "arrogated," so many other powers and duties that the sanitary officer of a generation ago would have great difficulty in understanding the scope of the work to-day.

Public opinion, in the last analysis, is responsible for the extension of these powers. The expansion of sanitary police functions, especially in the suppression of nuisances, has resulted from the growth of public opinion as to what constitute nuisances; forty years ago what we now define as "offensive trades" and relegate to certain prescribed sections of New York City flourished on many of the best streets. The force of public opinion has gradually branded one nuisance after another as "detrimental to health," and driven them to places where they are no longer an offence to the nostrils, the eyes, or the ears. Power to affect these removals, and to keep sources of nuisance under observation, has been given to boards of health in continually increasing measure, because the public has found that in the great majority of instances powers previously delegated had not been abused. It is this support of public opinion which has in recent years so increased the authority and multiplied the duties of sanitary officers.

Thus supported and uplifted by the public which they serve, the greatest of all the present problems confronting boards of health in this country, I have no hesitation in saying, is the responsibility of preserving the sanitary service from the evils of partisan politics.

The politician is nearly always the bitterest opponent of sanitary reform, because nearly every order for sanitary betterment touches the pocket of some of his constituents, who immediately run to the politician for relief. How important, then, from the standpoint of practical politics, it is that the party in power (I speak particularly of our cities) should have control of the sanitary officers and use their great authority to help friends and injure political foes. If the politician controls the sanitary officers, he controls the appointment of all subordinates, and soon demonstrates to them that he and not the nominal head of the sanitary office is the man to come to for instructions. When this occurs, the usefulness of a board of health is ended, and its maintenance is money thrown away, if not worse. Then, too, even if the office is not wholly in control of the politicians, they sometimes are able to secure the alteration or even the nullification of important orders, and the inevitable result is injury to the public that private interests may profit. The extension of the civil service law has made the subordinate sanitary officers in many cities independent of politicians' threats if they choose to be; but it does not so favorably affect the more important activities of sanitary bureau heads, who are still too much controlled by the appointing power. There will never be a radical improvement in this condition until our sanitary offices are taken entirely out of politics, and the incumbents appointed for life or during good behavior.

How to prevent the spread of infection will always be one of the chief problems for sanitary officers, and it continually presents new phases, new difficulties, as the density of population in great cities increases. This is particularly true of our seaboard cities, where there is a constant influx of immigrants, latterly of a class which is ignorant of the rudimentary principles of sanitary living, and of grossly filthy personal habits. These people have been dumped upon our coasts in swarms, several hundred thousand annually coming to New York City alone. Students of the immigration problem state that the more progressive elements of this new population move westward to take up unoccupied farm-lands, or find work in mines or mills, and that the most ignorant remain in the cities. We of New York can well believe this. After all, the enforcement of sanitary laws is bound up in the education of the ignorant and filthy to the objects of such laws; and so it is necessary for the sanitary authorities of New York and other maritime cities to carry on a never-ending campaign of education, in populations constantly renewed at the bottom of the ladder.

But new peoples are not merely ignorant and dirty; they often bear seeds of disease. The Federal Government has up to this time made no provision for the care of contagious sick immigrants in the largest American port, but has relied wholly on the local authorities for their detention and treatment. Two years ago we found that the sick immigrants were so crowding our contagious disease hospitals (then notoriously insufficient to care for New York's own contagious sick) that many citizens, who should have had first claim to attention, were being excluded. We notified the federal authorities that they must at once make preparations to isolate and treat contagious sick immigrants without the use of the city hospitals; and the result has been that the Government is building an island in the bay for isolation hospitals.

Much mischief has resulted from former lax medical inspection of immigrants, extending over many years. New York, and, I doubt not, other seaboard cities, are to-day troubled with many cases of contagious eye-disease, originally brought from Europe by immigrants and by them transmitted to their fellows in the East Side tenements, who are some of them only a degree less filthy than the new arrivals. To stamp out this disease will be the work of a generation, if not more, for its spread has been till lately entirely unchecked by the sanitary authorities, and its victims probably number many thousands.

It has seemed to us in New York that the best means of checking the spread of contagious disease, of which trachoma is only one comparatively unimportant element, was through the public schools. One of our leading sanitarians has well said that schools are the foci of infection. This is amply proved by a study of the reports of infectious disease cases in large cities; almost invariably the number of cases begins to increase with the assembling of pupils in the autumn, and continues large so long as the schools are in session. Rigid medical inspection in the schools is therefore absolutely necessary, and its advantages are manifest, for in New York City (which I may safely say has now the most highly developed system of medical school inspection in the country) the elaboration of the present method two years ago resulted in a diminution of contagious disease cases amounting to about 40 per cent. Incidentally, also, the death-rates of 1902 and 1903 fell to a point never before reached in the history of the city; with the lessened mortality among children particularly marked.

This system entails extreme care and considerable expense, for it demands the services of a competent medical inspector daily in every public school in the city.

His work is to exclude from the class-rooms all children under suspicion of infectious disease, and to notify the school authorities of the exclusions, with the reason for each, in order that exclusion may not be mistaken by them for truancy. At this point the diagnostician's work ends, and that of the school nurse begins. The nursing system was adopted with a view of providing minor medical attention for excluded children and of carrying into the tenement homes some elementary idea of the proper care of the sick, as well as incidental instruction in household sanitation. The school nurse is an adaptation of some of the principles of settlement work to the problem of handling school exclusions for minor contagious ailments, and, when she is a woman of experience and a graduate of some recognized training-school, as we require in New York, the successful results of her work are instantly manifest. One nurse can handle the exclusions from four or five schools, averaging from 500 to 1500 pupils each.

It is not required that the nurse shall give any attention to cases of contagious disease, such as scarlet fever, diphtheria, measles, and the like. That is and should be left to the ordinary operation of the bureau of contagious diseases, which has its established corps of diagnosticians and district medical inspectors. The routine handling of such cases involves, first, a rigid enforcement of rules regarding notification by the family physician of all contagious cases coming under his observation; second, the confirmation of the diagnosis by an expert medical inspector and his decision whether the case can be properly isolated in the home, or whether removal to the isolation hospital is necessary; third, the enforcement by the district medical inspector of the rules requiring a continuance of isolation during the full period of the disease.

Proper handling of a contagious disease bureau requires not only good judgment and strict obedience to department rules by medical inspectors in their work, but a well-organized system of keeping the records of all cases within the purview of the bureau. Another important aid to successful operation is the transmission daily to all school principals, teachers, librarians, and other persons having charge of children in ordinary places of assemblage, of complete and accurate lists of all contagious cases reported, and of the termination of other such cases and the disinfection of premises. This puts such persons on their guard, and undoubtedly checks the spread of contagion.

In spite of the enormous preponderance of evidence in favor of vaccination, we cannot deny that the prevention of small-pox is still a problem for local boards of health. I say local, for the handling of small-pox varies so greatly in different communities that the efficiency of one is often largely nullified by the neglect of another. Here again is a strong argument for centralization of disease-preventing and sanitary work under the control of a federal bureau. For example, in the first months of 1902, we in New York were confronted with an outbreak of small-pox which amounted almost to an epidemic. The disease was equally prevalent in other eastern cities. In that year, by vigorous effort, free public vaccination was performed upon nearly 25 per cent of our population of 3,500,000 persons, and there is reason to believe that private vaccinations reached an unusually large total, due to the alarm of the inhabitants over their danger, which was purposely not allayed by the sanitary authorities. In fact there was a genuine public awakening to the need of vaccination.

Cases of small-pox that year in New York numbered some 1900; the next year they fell to less than 100, although the disease continued very prevalent in many neighboring cities where there had been no determined effort to stamp it out. One result of this variation in practice was that New York was constantly visited by sporadic outbreaks of small-pox, brought from other cities. Fully half the 100 cases in 1903 were either of immigrants newly arrived from Europe or visitors from infected cities in the interior of the United States.

I believe that compulsory vaccination, so-called, is not necessary in most parts of our land. It may be demanded in countries having a less intelligent population than ours; but we of New York have found that we needed only to arouse public opinion on the necessity of vaccination to secure the results we wanted without any compulsion. Vaccination is a requirement of entrance into our New York public schools, and we have not, in my recollection, had a single case of small-pox in the schools so protected; but compulsion exercised upon adults often serves unnecessarily to arouse public feeling against the sanitary authority, and gives a handle to those ostrich-like scorners of facts, the anti-vaccinationists.

If we compare the variation in methods of contagious disease prevention as between the large cities and the small towns and rural districts, we find that in the latter few of the precautions taken in the cities are exercised in the country. This results from lack of proper facilities for isolation, and this lack is due to public indifference on the subject; for if the public realized how much the spread of disease could be checked by these means, provision for isolation hospitals and competent medical inspectors would be one of the first items of expenditure in their annual budgets.

As it is now, only the most intelligent of our secondary city governments make adequate provision for their contagious sick. Many others, of course, have buildings intended for that purpose, but these buildings too often consist of miserable shanties in the outermost confines of the city or village, and the inhabitants complete an ill-conceived work by calling these buildings "pest-houses" and thus branding them as places of horror to be avoided by every possible means. Such isolation hospitals destroy the value of property in the neighborhood.

Contrast such places with well-ordered isolation hospitals like those maintained in some of our smaller eastern cities, notably in New England, and the observer must realize that patients there treated not only have far better chances for recovery than if kept in the ordinary home, but that they cease to be a source of danger to the community.

Until such handling of contagion becomes general in our country, negligent communities will continue to nullify the efforts of those which take proper care of their inhabitants. If the stimulus to such action came as an order from a federal board, having jurisdiction and punitive powers throughout the country, the popular knowledge on this subject would grow more rapidly, and the popular conscience would be more quickly awakened.

Discovery and development of the serum treatment for certain infectious diseases, notably diphtheria, has in the last ten years brought new problems to sanitary officers, both in practice and research. It may safely be said that the labors of the bacteriologist have in this time done more than any other one thing in the prevention of infectious disease. Speaking as a layman, of course, I am led to believe that preventive medicine will in the next generation make its greatest progress along the lines of bacteriological research. We are on the eve of still more important discoveries in this direction, and it would not be rash to predict that serums for the successful treatment of tuberculosis, pneumonia, and scarlet fever will be the next great steps. The importance of such results it is impossible to exaggerate.

Consider for a moment the beneficial effects already attained by the anti-diphtheritic serum. I may cite the work of New York City, where the work was first instituted in this country, and where it has been most highly developed. In 1893, New York's case-fatality from diphtheria was 36.4 per cent, and in 1894 it was 29.7 per cent. New York having in 1892 established the first bacteriological laboratory under municipal control, the preparation of serum for diphtheria treatment was begun in 1894, and in 1895 the distribution of this serum was begun. It was given free to all public institutions and to all persons who certified, through the attending physicians, that they were too poor to pay the price charged for it, which was fixed at a point only high enough to cover the cost of manufacture and incidental expenses of the laboratory; a staff of medical inspectors was also designated to administer the antitoxin free upon request of an attending physician.

In that year, due almost entirely, I am convinced, to the use of this new remedy, the case-mortality fell to 19.1 per cent, and it has steadily decreased until in 1903 it had fallen to 11.1 per cent. It is now the practice also to administer immunizing doses of antitoxin to healthy members of a family having a case of diphtheria, and in the last eight years upwards of 13,000 persons have been so immunized by department inspectors and family physicians. Of the persons so immunized, .3 of one per cent contracted the disease, and one case terminated fatally. Could any stronger testimony than these figures be offered as to the efficiency of diphtheria antitoxin in the cure and prevention of the disease?

Naturally enough, such results have led to the establishment of other laboratories for the preparation of this serum. Some are maintained by state authorities, notably in Massachusetts, but the larger ones are now under private auspices.

High prices are charged for serums by manufacturing chemists, and there is no means of testing their efficiency comparable to the records of public laboratories. It therefore would seem to be a reasonable precaution, in the interest of the public health, that these private laboratories should be placed under strict governmental supervision and control, if, indeed, the manufacture of serums should not be one of the functions of a national board of health, organized according to plans which I have mentioned, and which are by no means novel. Products of public laboratories might be distributed free or at small cost, and thus be made far more effective in the prevention of disease, while control of the laboratories by recognized sanitary authorities would be a more satisfactory guarantee of the potency and uniformity of their serum products. A highly organized governmental laboratory service would also offer splendid opportunities for research work in a field the enormous importance of which few people are yet in a position to realize.

One of the most hopeful signs of progress in popular appreciation of sanitary endeavor is the general interest now awakening in methods for the prevention of tuberculosis. Medical men are everywhere agitating for better facilities to fight this disease, the worst enemy of the human race, and lay associations are taking steps to establish sanitariums for the reception of patients. This work is a stupendous one, and we have thus far only touched its edge. Efforts to discover a serum for the cure of the disease, though thus far disappointing, have already much increased medical knowledge of the subject.

It is not enough that the world should wait on the researches of the bacteriologist. Our cities are full of consumptives, spreading infection among their fellows in spite of all efforts of the sanitary authorities to instruct them in personal precautions. We must have sanitariums and hospitals of large capacity for the reception of cases in all stages of the disease. The cost will be great; but tuberculosis claims most of its victims at a time when their usefulness in industrial pursuits is greatest, and it can be amply proved that the cost of their care and cure would be small indeed in comparison with the loss the community suffers by being deprived of their services. Money spent in erecting and maintaining sanitariums would be saved in almshouses and orphan asylums.

Even when such places of reception for consumptives are afforded in anything like sufficient measure, there will still be a large class of infected wage-earners who cannot leave their regular occupation because their earnings are needed to support dependent members of the family. For all such the sanitary authorities must exercise greater care. This is one of the great objects in improving the conditions of labor, the ventilation and sanitation of factories and workshops, and the improvement of the tenements in which people of this class are forced to live. Equally must the conditions surrounding child labor be the subject of still further investigation and regulation.

Development of the cognate science of vital statistics is highly important in the study of methods for the prevention of disease. It helps to measure progress and point out the next steps necessary. But its aim is of course far wider than this; the record obtained by this registration system are of basic importance not only to the sanitarian, but to the student of sociology in all the ramifications of his work, in political economy, geographical race distribution, education, etc. Add to this their importance in private affairs, where they are often the final arbiters in disputes over titles and inheritance, and we have ample reason for using the proceeds of taxation liberally in developing the work of the vital statistician.

In no respect have the powers and responsibilities of boards of health developed more in the last generation than in the regulation of public nuisances. I refer particularly, of course, to the regulation of nuisances in cities, because the increase of population in restricted areas in cities has in itself created new sources of nuisance and brought new problems for solution by the sanitarian. The greater demand for comfort in city life, and the realization that the public health is in large measure dependent upon a restriction of many things which in the past have made for discomfort, have led to the institution and enforcement of a new body of sanitary ordinances of a scope not dreamed of even as recently as twenty years ago. These have almost revolutionized sanitary practice and have added enormously to the powers and duties of sanitary officers.

It is noteworthy that the public demand for relief in this direction has greatly expanded the list of nuisances which have been placed under sanitary control. To the duty of protecting the public health has been added that of protecting the public comfort. For example, I imagine it would be very difficult for sanitary officers to prove on the trial of every case that a smoke nuisance is directly injurious to the public health; yet so strong is public opinion in favor of enforcement of this ordinance that the sanitary authorities who proceed vigorously under it have little difficulty in suppressing such nuisances, even when the prosecution of offenders reaches the municipal courts.

This is all a very new development in sanitary practice. The growth of manufacturing by steam-power in large cities has greatly increased the use of coal in boiler plants of large capacity. Of late, because of the higher prices for anthracite, the use of bituminous coal for manufacturing purposes has come into vogue. Imperfect combustion, the result of careless firing, creates a nuisance. Suppression of this nuisance should not be confined to arrest and punishment of the offenders; instruction in means to avoid nuisance should accompany it.

Akin to the smoke nuisance is that from dust. Bacteriological study has shown conclusively that dust is a carrier of disease-germs, and therefore a menace to public health. Here is the greatest argument for clean streets and for improved methods of cleaning them. In the New York tenement districts we have had great success from the general use of asphalt pavement, which can be washed with a hose, and so cleaned without raising dust. The great thing in getting rid of dust is not to *move* it but to *remove* it. This applies to the dust problem in houses, and in theaters, schools, churches, and all other places of public assembly. Such places in New York were a year or two ago, under our instructions, first brought under general sanitary inspection, with excellent and rather remarkable results, considering how large a number of orders we had to issue to have them put in proper sanitary condition. This work may be well adapted to a countless number of public and semi-public buildings in cities, for the places which every one year after year assumes to be in fairly good condition are often the ones which really demand most careful attention from the sanitary authorities.

As a vehicle for the transmission of the germs of tuberculosis, dust in places of public occupancy, like railway and street-railway cars and ferry-boats, should be rigorously fought. The matting and carpets upon the floors of public conveyances are sources of danger, and should either be done away with entirely or cleaned and fumigated at frequent intervals. Our American habit of spitting everywhere but in proper receptacles, undoubtedly conveys infectious disease, and every city should pass and enforce an anti-spitting ordinance. New York has had a course of public education in this respect, and the nuisance is very greatly reduced, although hundreds of men, some of them intelligent enough to know better, figure in the police courts every year as prisoners on this account.

Noise, as an element of public nuisance, demands increased attention from the sanitary officer. Its injurious effect on the health of individuals is beyond question. But the authorities must distinguish carefully as to whether a particular noise is a public or merely a private nuisance, and whether it is a necessary concomitant of something of public utility.

Noise nuisances in connection with public utilities are in some sense necessary. In cities the trolley-car is often a source of nuisance to the inhabitants of the streets through which it passes, due to excessive ringing of bells, and the operation of cars with unevenly worn wheels. Both these nuisances can be minimized, either by calling the attention of the railway operators to them, or, failing relief, by prosecution in the courts. The use of flat-wheeled cars is as much a waste of power and equipment as is imperfect combustion of fuel, and, in the interest of the public health, should be suppressed with equal severity.

Offensive and dangerous trades also call for attention by the sanitary authorities. Most cities which have given proper care to this subject have restricted their offensive trades, such as slaughter-houses, gas-plants, and the like, to certain areas, and allowed their operation only under permit from the board of health, revocable for violation of the sanitary ordinance. This system appears to work very satisfactorily for the public, so long as the sanitary officers are neither negligent nor venal.

It is an interesting fact in connection with the handling of nuisances of this class that many improvements demanded by the sanitary authorities, such as the inclosing of rendering-vats to prevent the escape of ill-smelling vapors or the collection and removal of nuisance-making liquid refuse, have in themselves resulted in cheapening manufacture; the discussions of methods for the innocuous removal of such waste matter has opened the way for its profitable employment for the making of one or more of the numerous by-products out of which large profits are gained.

These results might never have been achieved without the correctional action of the authorities.

The time has passed for the establishment of any of the so-called offensive trades within the built-up portions of cities. Existing plants should be gradually removed, with due regard to the vested interests involved, and no more should be allowed to come in. Railway transportation of dressed beef has become so general that there is no longer any excuse for the building of slaughter-houses in eastern cities. Not only is this best on economic grounds, but the transportation of live-stock for longer distances than absolutely necessary is to be opposed on medical and humanitarian grounds. Neither is there any reason, but the inertia of their owners, for the maintenance of manufacturing plants in the midst of cities, and their establishment should be vigorously opposed by the sanitary authorities.

The so-called dangerous trades offer a field thus far little worked by the sanitarian in this country, although the subject has had much attention abroad. Here we have hardly any legislation under which the sanitary authorities can take radical action to safeguard the life and health of persons employed in those trades, and therefore they may hardly be said to be under official control. There are many trades, however, in which the ordinary processes of manufacture induce disease, and others also which offer means for the spread of infection. All will repay study by the sanitarian, with a view to remedial legislation.

Jurisdiction of boards of health over public supplies, such as water and milk, is already well developed in some states and cities, and much valuable work has been done in respect to the sanitary purity of these necessaries of life. Negligence by the public authorities, however, is still resulting, year by year, in outbreaks of typhoid and other enteric troubles communicated in impure water or milk. For evidence of this we have recent typhoid epidemics in Ithaca and Watertown, New York, and Butler, Pennsylvania.

The very rapid growth of our cities and towns and the improper disposal of their sewage are causing general pollution of many water-sources, and making it more difficult either to find pure water-supplies or to keep existing supplies safe from infection. The only remedy for this increasing menace is filtration, and that on a large scale and under constant supervision by sanitarians and bacteriologists. This work is very costly, but its maintenance after the installation is complete will amply repay the expense, in the saving of life and the preservation of health. Equally important are precautions for the treatment of sewage. Bacterial purification of the liquid refuse of cities and towns is now coming into use, with salutary effect; but too often municipalities which have installed such systems imagine that their work is done, when in fact such methods of sewage disposal require constant expert attention in order to insure their maximum efficiency.

Thorough sanitary control of watersheds involves not only the removal therefrom of all possible sources of infection and the preparation of reservoirs by the elimination of all decaying vegetable matter; there is also demanded an efficient, unremitting inspection of all sources of water-supply, with frequent chemical and bacteriological examination of the water itself. Statistics gathered in the course of such investigations are all-important in tracing the nature and sources of pollution. The extension of existing watersheds and the taking of new ones, to meet the demand for more water due to the growth of our cities, make such investigations imperative for the maintenance of the public health. Coöperation between state and municipal authorities to this end has already been productive of much benefit, and for this reason it is highly important that these two divisions of sanitary workers should operate in accord; even better results might be achieved if they could be coördinated under the control of a national sanitary body.

Bacteriological disclosures of the transmission of disease-germs in milk, and of the dangers resulting from improper handling of this product, have brought it more firmly under sanitary supervision. The first step in the cities, of course, was to bring all milk-dealers within the control of the board of health by prohibiting the sale of milk without a permit. The next was to revoke permits when milk found on sale fell below the standard adopted. It was frequently found that the retailer was the innocent victim of an unscrupulous wholesaler or shipper, consequently it became necessary for the municipal sanitarian to reach out into the country districts and investigate the conditions at dairy farms. With the investigation went some instruction in methods of producing clean milk, by which the honest farmer might profit. The establishment of model dairy farms by men of wealth has also taught by example, and the high prices obtainable in city markets for high-grade milk have stimulated the farmer to continually greater effort. With this campaign of education has come a demand on the railways for the proper icing of milk-cans in transit.

Milk is a most favorable medium for the propagation of germ-life, especially at temperature above 50° Fahrenheit. In this condition it is often found to have a toxic effect, particularly when used for infant feeding; consequently failure on the part of the sanitary authorities to prevent the sale of such milk has the immediate and direct result of advancing the rate of infant mortality.

Regulation of the sale of other foodstuffs has been less highly developed. In some centres there has been established a fairly efficient system for the inspection of beef cattle, but there is no doubt that the meat of tuberculous animals is sold in considerable quantity in all our large cities. Scientists have not yet definitely determined whether or not tuberculosis can be thus transmitted to human beings, but there is still adequate reason why the sale of infected beef should be absolutely stopped and the sellers punished.

The danger of typhoid infection through the medium of shell-fish is now so well established that we need have no question of it at this late date. No more clean-cut instance of this can be found in all medical history than in the epidemic of typhoid fever at Wesleyan University ten years ago. Investigation by Professor Conn and others demonstrated conclusively that the disease had its origin in Fair Haven, where the oysters eaten by these Wesleyan students had been fattened in an infected stream. It may be noted also that recent experiments in the bacteriological laboratory of the New York Department of Health have tended to show that the icing of infected shellfish does not destroy the virility of the germ-life therein.

With these facts accepted, what excuses the sanitarian from maintaining a most careful supervision over the culture and sale of shellfish? Especial attention should be given to the so-called "fattening" process, which is most often conducted in the brackish waters of streams adjacent to tidewater. The liability to infection in such waters is too obvious for argument, and the fattening process should either be stopped, or restricted to locations where there is no danger of pollution.

An important field is now opening to the sanitarian in the investigation of manufactured food-products. The extent to which commercial adulteration and substitution is now practiced would be absolutely incomprehensible to the layman. Competition in trade has become so keen and the substitution of inferior constituents in foods so general that the honest manufacturer has hardly a chance to succeed. Even to name a small part of the many frauds of this character would consume more than the time allotted to this paper. The use of injurious preservatives has also been practiced to a scandalous extent. The only remedy for this evil condition will be the passage and enforcement of a federal pure food law; such a measure has already been before Congress, but in the absence of an aroused public opinion, the mysterious influences which bar the way of much good legislation at Washington have been able to kill it. Several of the states already have pure food laws, and a beginning has been made under them, but this reform will only come after one of the longest and hardest fights which the public sanitarian has ever known.

Much the same opportunity is offered in a campaign against the vender of patent medicines and secret nostrums. Few people understand the extent to which these articles undermine the public health, and there has been little or no attempt to assume official control over their production and sale.

These nostrums are of several kinds. Some of them are prescriptions which have been commercialized by some sharp business-man, with all the help of advertising and guarantees of the remedy as a "cure-all." Gullible people, who seem to be legion, are led into the error of imagining that all diseases of the same general description will yield to the same remedy; they fail to recognize the important factor of idiosyncrasy, and the result is that nine out of every ten persons using such a remedy are not helped and may be injured in health, as they surely are in pocket.

In this class of nostrums must be ranked the various headache powders, now for sale everywhere. Almost invariably these contain drugs which should only be prescribed by physicians, and then only with extreme caution.

In another kind of nostrums the active principle is some powerful drug or stimulant, the use of which speedily becomes a vice. For example, many so-called catarrh cures have cocaine as their active agent; others, again, which are advertised to cure every ill, or to break the user of the liquor habit, are loaded with alcohol, which produces a passing stimulation, but leaves the patient in worse state than before. All these are swindles of the most dangerous character, and it is the plain duty of the public health officer to secure their suppression.

The official chemist is called upon also to investigate and stop the sale of impure and substituted drugs. It is not too much to say that the drug trade is flooded with such deceptions on which the public is being worse defrauded year by year, as the evil grows.

The remedy is official control. Makers of patent medicines, nostrums, pills, etc., should be required to place upon each bottle or packet the exact ingredients it contains, and should be prosecuted for any deviation which can be shown to be detrimental to the health of persons using the remedy, or designed to perpetrate upon them a commercial fraud. Further, the Federal Government, or local boards of health, or both, should institute a division for the inspection of these goods, and for a more careful general inspection of pharmacies, to determine whether all compounders of prescriptions are duly licensed, whether a record is kept of all poisons sold, and whether the drugs there offered to the public are pure and not substituted. To start a work of this kind will mean a fight all along the line. The manufacturers of nostrums and adulterated drugs are a very wealthy and powerful class in the community, and they will oppose all remedial legislation to the uttermost. The only thing they cannot stand against is aroused public opinion; and the sanitary officer must see that an intelligent public opinion on this important question shall be created.

Any discussion of the present problems of the sanitarian, however brief and superficial, would be incomplete without some mention of the auxiliary forces at work. Chief of these is the wide and growing public interest in sanitary problems and the evident desire of municipal and village communities everywhere to learn and apply the most rational and effective methods to their particular circumstances and situation. When we recall that men still in the prime of life saw the beginnings of municipal sanitation in the United States, we must realize the great progress that has been made.

It is not conceivable that we shall stop with this degree of attainment. All the great sanitary questions, the prevention of disease and nuisance, the promotion of municipal cleanliness, the disposal of sewage, the utilization of wastes, and a score of other problems which might be mentioned, are still in their infancy, and the handling of them fifty years hence will make our present-day methods appear almost prehistoric. In all this progress, the physician, the bacteriologist, the chemist, and the sanitary engineer will combine their efforts, and the public opinion will support and aid them.

Such a body of public opinion is now being educated in our schools, where the physician, the nurse, and the sanitary inspector are object-lessons in municipal hygiene; in the literature of the day, which is giving especial attention to sanitation in its broadest sense; and, not least, in the numberless voluntary associations in which public-spirited citizens, prominently the women, are striving to correct municipal abuses and aid the sanitary authorities in estabishing a higher standard of public health. With such duties and such aids, continued progress is imperative and sure.

SHORT PAPERS

Dr. Arthur R. Reynolds, Commissioner of Health, City of Chicago, presented a paper containing a plea for twelve-hour milk, in which was discussed the fact that in all state laws and city ordinances not a word is contained as to the age of the milk which is sold.

Dr. J. N. Hurty, Secretary of the State Board of Health of Indiana, presented a paper to this Section on "Dust," and its promotion of infectious diseases.

SECTION B — PREVENTIVE MEDICINE

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(*Hall* 13, *September* 21, 3 *p. m.*)

CHAIRMAN: DR. JOSEPH M. MATHEWS, President of the State Board of Health, Louisville, Kentucky.
SPEAKER: PROFESSOR RONALD ROSS, F. R. S., School of Tropical Medicine, University College, Liverpool.
SECRETARY: DR. J. N. HURTY, Indianapolis.

THE LOGICAL BASIS OF THE SANITARY POLICY OF MOSQUITO-REDUCTION

BY RONALD ROSS

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THE great science of preventive medicine is often called upon to consider new policies of public sanitation, which, whether they ultimately prove successful or not, are always of profound interest and importance to mankind. Quite recently a new measure of this kind has been proposed, which in the opinion of many promises to rank with house-sanitation and preventive inoculation as a means of saving human life on a large scale. Unfortunately, its value has not yet been clearly demonstrated — with the result that it is not being employed as largely as some of us hoped would be the case. I feel, therefore, that I cannot better acknowledge the honor you have done me in inviting me to address you to-day than by attempting to discuss this important theme — in the hope that the discussion may prove profitable to the cause of public health. The new sanitary policy to which I refer is that which aims at the reduction of disease-bearing insects, especially those which are the disseminating agents of malaria, yellow fever, and filariasis.

I presume that it is scarcely necessary to discuss the evidence which has established the connection between various insects and arthropods and many diseases of man and of animals. The fact that the pathogenetic parasites which produce those great scourges of the tropics just mentioned are carried by gnats is now too well known to require reiteration. It is necessary only to remind you that the gnat acts as an intermediary, becoming infected when biting infected persons and, some weeks later, infecting healthy persons in its turn — the parasite passing alternately from insect to man. The hypothesis that the infection in these diseases may be produced in any other manner than by the bite of gnats has not been justified by any recorded experiments or by any substantial arguments; and we may, therefore, assume for the present that if we could exterminate the intermediary agents, the gnats, in a locality, we could also exterminate there the diseases referred to. But here we enter upon ground which in the opinion of many is much less secure. While some believe in the possibility of reducing gnats in given localities and consider that the point has been proved by experiment, others are much more skeptical and hold that the experiments were not sound. This state of uncertainty naturally causes much hesitation in the adoption of measures against gnats, and, therefore, possibly a continued loss of life by the diseases occasioned by them; and I, therefore, propose to sift the matter as carefully as time will allow.

In the first place, we should note that experiments made in this connection have not been very satisfactory, owing to the fact that no accurate method has yet been found for estimating the number of gnats in any locality. We can express our personal impressions as to their numbers being small or large; but I am aware of no criterion by which we can express those numbers in actual figures. We cannot anywhere state the exact number of mosquitoes to the square mile or yard, and we cannot, therefore, accurately gauge any local decrease which may have resulted from operations against them. A method of doing this may be invented in the future; but for the present we must employ another means for resolving the problem — one which has given such great results in physics — namely, strict logical deduction from ascertained premises.

As another preliminary we should note that mosquito-reduction is only part of a larger subject, namely, that of the local reduction of any living organisms. Unlike particles of matter (so far as we know them) the living unit cannot progress through space and time for more than a limited distance. The diffusion of living units must, therefore, be circumscribed — a number of them liberated at a given point will never be able to pass beyond a certain distance from that point; and the laws governing this diffusion must be the same for all organisms. The motile animal is capable of propelling itself for a time in any direction; but even the immotile plant calls in the agency of the winds and waters for the dissemination of its seeds. The extent of this migration, whether of the motile or the immotile organism, must to a large degree be capable of determination by proper analysis; and the logical position of the question of local reduction depends upon this analysis.

The life of gnats, like that of other animals, is governed by fixed laws. Propagation can never exceed, nor mortality fall below, certain rates. Local conditions may be favorable either to the birth-rate or to the death-rate; and the local population must depend upon the food-supply. Diseases, predatory animals, unfavorable conditions, and accidents depress the density of population; and in fact local reduction, that is, artificial depression of the density of population, practically resolves itself into (*a*) direct destruction and (*b*) artificial creation of unfavorable conditions.

Let us now endeavor to obtain a perfectly clear picture of the problem before us by imagining an ideal case. Suppose that we have to deal with a country of indefinite extent, every point of which is equally favorable to the propagation of gnats (or of any other animal); and suppose that every point of it is equally attractive to them as regards food-supply; and that there is nothing — such for instance as steady winds or local enemies — which tends to drive them into certain parts of the country. Then the density of the gnat population will be uniform all over the country. Of course, such a state of things does not actually exist in nature; but we shall nevertheless find it useful to consider it as if it does exist, and shall afterwards easily determine the variations from this ideal condition due to definite causes. Let us next select a circumscribed area within this country, and suppose that operations against the insects are undertaken inside it, but not outside it. The question before us is the following: How far will these operations affect the mosquito-density within the area and immediately around it?

Now the operations may belong to two categories — those aimed at killing the insects within the area, and those aimed at checking their propagation. The first can never be completely successful; it is in fact impossible to kill every adult winged gnat within any area. But it is generally possible to destroy at least a large proportion of their larvae, which, it is scarcely necessary to remind you, must live for at least a week in suitable waters, and which may easily be killed by larvacides, or by emptying out the waters, or by other means. This method of checking propagation consists, in the case of these insects, of draining away, filling up, poisoning, or emptying out the waters in which they breed. Obviously the ultimate effect is the same if we drain away a breeding-pool or if we persistently destroy the larvae found in it; though in the first case the work is more or less permanent, and in the second demands constant repetition. If we drain a breeding-area we tend to produce the same effect at the end of a year as if we had destroyed as many gnats as otherwise that area would have produced during that period. Thus, though we cannot kill all mosquitoes within an area, even during a short period, we can always arrest their propagation there for as long as we please, provided that we can obliterate all their breeding-waters or persistently destroy all their larvae — which we may assume can generally be done for an adequate expenditure. We must, therefore, ask what will be the exact effect of completely arresting propagation within a given area under the assumed conditions?

The first obvious point is that the operation must result in a decrease of mosquitoes. If we kill a single gnat there must be one gnat in the world less than before. If we kill a thousand every day there must be so many thousands less at the end of a given period; and the arrest of propagation over any area, however small, must be equivalent to the destruction of a certain number of the insects. But this does not help us much. It may be suggested that, after the arrest of propagation over even a considerable area, the diminution of mosquitoes within the area remains inappreciable. What is the law governing the percentage of diminution in the mosquito density due to arrest of propagation within an area?

The number of gnats (or any animal) within an area must always be a function of four variables, the birth-rate and death-rate within the area, and the immigration and emigration into and out of it. If we could surround the area by an immense mosquito-bar, the insects within it (after the death of old immigrants) would consist entirely of native insects; on the other hand, if we arrest propagation, the gnat population must hereafter consist entirely of immigrants. The question, therefore, resolves itself into this one: What is — what must be — the ratio of immigrants to natives within any area? What factors determine that ratio?

Ceteris paribus, one factor must be the size of the area. If the area be a small one, say of ten yards radius, suppression of propagation will do little good, because the proportion of mosquitoes bred there will be very small (under our assumed conditions) compared with those which are bred in the large surrounding tracts of country, and which will have no difficulty in traversing so small a distance as ten yards. But if we completely suppress propagation over an area of ten miles radius, the case must be very different — every gnat reaching the centre must now traverse ten miles to do so. And if we increase the radius of the no-propagation area still further, we must finally arrive at a state of affairs when no mosquitoes at all can reach the centre, and when, therefore, that centre must be absolutely free from them. In other words, we can reduce the mosquito-density at any point by arresting propagation over a sufficient radius around that point.

But we now enter upon more difficult ground. How large must that radius be in order to render the centre entirely mosquito-free? Still further, what will be the proportion of mosquito-reduction depending upon a given radius of anti-propagation operations? What will be that proportion, either at the centre of operations, or at any point within or without the circumference of operations? The answer depends upon the distance which a mosquito can traverse, not during a single flight, but during its whole life; and also upon certain laws of probability, which must govern its wanderings to and fro upon the face of the earth. Let me endeavor to indicate how this problem, which is essentially a mathematical one of considerable interest, can be solved.

Suppose that a mosquito is born at a given point, and that during its life it wanders about, to and fro, to left or to right, where it wills, in search of food, or of mating, over a country which is uniformly attractive and favorable to it. After a time it will die. What are the probabilities that its dead body will be found at a given distance from its birthplace? That is really the problem which governs the whole of this great subject of the prophylaxis of malaria. It is a problem which applies to any living unit. We may word it otherwise, thus — suppose a box containing a million gnats were to be opened in the centre of a large plain, and that the insects were allowed to wander freely in all directions — how many of them would be found after death at a given distance from the place where the box was opened? Or we may suppose without modifying the nature of the problem that the insects emanate, not from a box, but from a single breeding-pool.

Now what would happen is as follows: We may divide the career of each insect into an arbitrary number of successive periods or stages, say of one minute's duration each. During the first minute most of the insects would fly towards every point of the compass. At the end of the minute a few might fly straight on and a few straight back, while the rest would travel at various angles to the right or left. At the end of the second minute the same thing would occur — most would change their course and a very few might wander straight on (provided that no special attraction exists for them). So also at the end of each stage — the same laws of chance would govern their movements. At last, after their death, it would be found that an extremely small proportion of the insects have moved continuously in one direction, and that the vast majority of them have wandered more or less backward and forward and have died in the vicinity of the box or pool from which they originally came.

The full mathematical analysis determining the question is of some complexity; and I cannot here deal with it in its entirety. But if we consider the lateral movements as tending to neutralize themselves, the problem becomes a simple one, well known in the calculus of probabilities and affording a rough approximation to the truth. If we suppose that the whole average life of the insect contains n stages, and that each insect can traverse an average distance l during one such stage or element of time, then the extreme average distance to which any insect can wander during the whole of its life must be nl. I call this the limit of migration and denote it by L, as it becomes an important constant in the investigation. It will then be found that the numbers of insects which have succeeded in reaching the distances nl, $(n-1)l$, $(n-2)l$, etc., from the centre will vary as twice the number of permutations of $2n$ things taken successively, none, one, two, three at a time, and so on — that is to say, as the successive coefficients of the expansion of 2^{2n} by the binomial theorem. Suppose, for convenience, that the whole number of gnats escaping from the box is 2^{2n} — a number which can be made as large as we please by taking n large enough and l small enough — then the probabilities are that the number of them which succeed in reaching the limit of migration is only 2; the number of those which succeed in reaching a distance one short stage of this, namely, $(n-1)l$, is $2.2n$; of those which reach a stage one shorter still is

$$2\frac{2n(2n-1)}{2'}$$

and so on. Hence the whole number of gnats will be found arranged as follows:

Distance from centre	nl	$(n-1)l$	$(n-2)l$	$(n-3)l$	etc. total.
Number of gnats	$2+$	$4n+$	$2\frac{2n(2n-1)}{2'}+$	$2\frac{2n(2n-1)\,(2n-2)}{3'}$	$+$etc.$=2$

It therefore, follows from the known values of the binomial coefficients that if we divide the whole number of gnats into groups according to the distance at which their bodies are found from the box, the probabilities are that the largest group will be found at the first stage, that is, close to the box, and that the successive groups, as we proceed further and further from the box, will become smaller and smaller, until only a very few occur at the extreme distance, the possible limit of migration. And the same reasoning will apply to a breeding-pool or vessel of water. That is, the insects coming from such a source will tend to remain in its immediate vicinity, provided that the whole surrounding area is uniformly attractive to them.

The following diagram will, I hope, make the reasoning quite clear.

We suppose that 1024 mosquitoes have escaped during a given period from the central breeding-pool P, and we divide their subsequent life into 5 stages — the numbers 1024 and 5 being selected merely for illustration. Rings are drawn around the central pool in order to mark the distance to which the insects may possibly wander up to the end of each stage; and the continuous line shows the course followed by one which has wandered straight onward all its life and has died at the extreme limit to which an insect of its species can generally go, namely, the outermost circle, *L*. On the other hand, the dotted line shows a course which is likely to be followed by the largest number of the 1024 insects liberated from the pool — that is to say, a quite irregular to-and-fro course, generally terminating somewhere near the point of origin. The numbers placed on each ring show the number of mosquitoes calculated from the binomial coefficients when $n=5$, which are likely to reach as far as that ring at the time of their death. Thus only 2 out of the 1024 mosquitoes are ever likely to reach the extreme limit; while, on the other hand, no less than 912, or 89 per cent, are likely to die somewhere within the second ring around the centre.

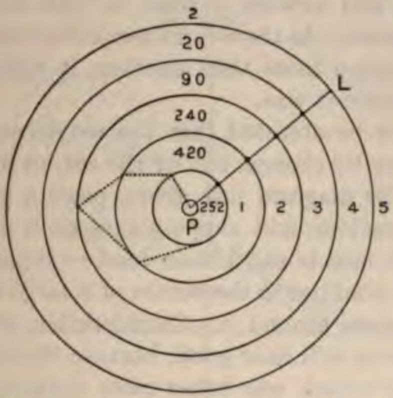

Diagram I. The chance-distribution of mosquitoes. *P*, central breeding-pool. *L*, limit of migration. The numbers denote the proportions of 1024 mosquitoes starting from *P* which die at the distances 1, 2, 3, 4, 5, respectively. The continuous line denotes a continuous migration always in one direction; the dotted line, the usual erratic course.

The same reasoning will apply whatever may be the number of mosquitoes liberated from the pool, or the number of stages into which we arbitrarily divide their subsequent life. Suppose, for example, that 1,048,576 mosquitoes escape from the pool and that we divide their life into 10 stages. Then only 2 of all these insects are ever likely to reach the extreme limit of the outermost circle; only 40 will die at the next circle; only 190 at the next; and so on — the large majority perishing within the circles comparatively close to the point of origin.

This fact should be clearly grasped. The law here enunciated may, perhaps, be called *the centripetal law of random wandering*. It ordains that when living units wander from a given point *guided only by chance*, they will always tend to revert to that point. The principle which governs their to-and-fro movements is that which governs the drawing of black and red cards from a shuffled pack. The chances against our drawing all the twenty-six black cards from such a pack without a single red card amongst them are enormous, as are the chances against a mosquito, guided only by chance, always wandering on in one direction. On the other hand, just as we shall generally draw black and red cards alternately from the pack, or nearly so, so will the random movements of the living unit tend to be alternately backward and forward — tend, in fact, to keep it near the spot whence it started. As there is no particular reason why it should move in one direction more than another, it will generally end by remaining near where it was.

But it will now be objected that the movements of mosquitoes are not guided only by chance, but by the search for food. To study this point, take the diagram just given, place a number of pencil-dots upon it at random, and suppose that each pencil-dot denotes a place where the insects can obtain food — suppose, for example, that the breeding-pool lies in the centre of a large city and that the pencil-dots are houses around it. Consideration will show that the centripetal law must still hold good, because there is no reason why the insects should attack one house more than another. There is no reason why a mosquito which has flown straight from the pool to the nearest house should next fly to another house in a straight line away from the pool, rather than back again, or to the right or left. The same law of chance will continue to exert the same influence, and the insects will always tend to persecute most those houses which lie in the immediate vicinity of their breeding-pool. Even when there are many pools scattered about among the houses, there is no reason why, after feeding, the mosquitoes will go to one rather than to another; and the result must be that in general they will tend to remain where they were.

Self-evident as this argument may now appear, it is not understood by many who write on the subject and who seem to think that mosquitoes radiate from a centre and shoot forever onward into all parts of the country as rays of light do. Accepting this fallacy without question, they argue that it is useless to drain local breeding-pools because of the influx of mosquitoes from without. Such an influx certainly always exists; but I shall now endeavor to show that it cannot generally compensate for local destruction.

Let us consider a tract of country over which numbers of mosquito breeding-pools are scattered, with houses and other feeding-places lying among them. Suppose we draw a straight line across this country and drain away all the pools to the right of it, leaving all those to the left of it intact. Then all the insects on the left of the line must be natives of that part; and all those on the right of it must be immigrants which have crossed over the line from the left. How many mosquitoes will there now be on the right side, compared with those on the left side? The following diagram will enable us to consider this question more conveniently.

First, examine the state of affairs before the drainage was effected. We may suppose that mosquitoes were then breeding fairly uniformly over the whole country, and that their density was much the same on both sides of the line. A certain amount of migration across the line, both from right to left and from left to right, must always have been going on; and since the density was equal on both sides, this migration must also have been *equal and opposite* — that is, as many emigrants must have been constantly passing from right to left as from left to right. Now, after the drainage has been effected the following changes occur. The insects breed as before on the left of the line, and some continue as before to cross over it into the drained country; but, in the latter, on the right of the line, propagation is entirely checked and, moreover, the migration from it to the left of the line, which used to exist, now ceases. Hence not only must there be a decrease of mosquito-density on the right of the line, due to the local cessation of breeding, but also a decrease on the left of the line, due to the cessation of the migration from the right which formerly took place — that is to say, the drainage has affected the mosquito-density not only up to the line of demarkation, but beyond it. And moreover, since the migration was formerly equal from both sides of the line, it follows that now, after the drainage, the loss on the left side of the line due to the cessation of immigration from the right is exactly equal to the gain on the right due to the continuance of the immigration from the left. That is to say, the mosquitoes gained by immigration into the drained country must

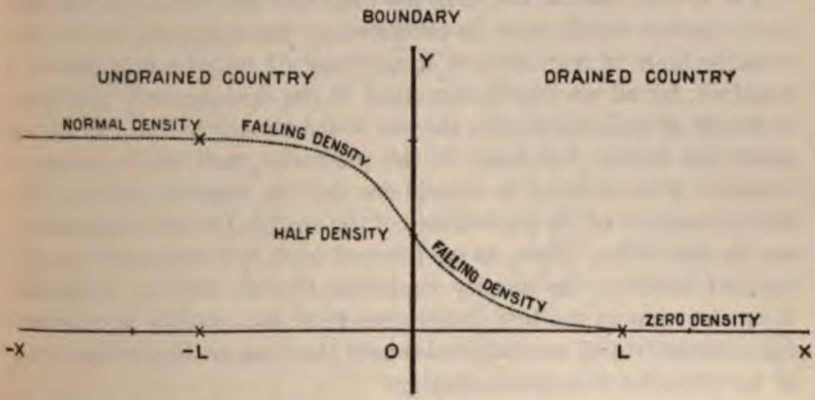

DIAGRAM II. Curve of falling mosquito-density due to drainage on right boundary. *L* and $-L$ are the limit of migration on either side of the boundary.

be exactly lost by the undrained country. This fact can be seen to be obviously true if we imagine an immense mosquito-bar put up along the line of demarkation so as to check all migration across it, when, of course, the mosquito-density would remain as at first on the left, and would become absolute zero on the right: then on removing the mosquito-bar an overflow would commence from left to right, which would increase the density on the right by exactly as much as it would reduce the density on the left.

The dotted line on the diagram indicates the effect on the mosquito-density which must be produced by the drainage. If L is the possible limit of migration of mosquitoes (it may be one mile or a hundred, for all we know), the effect of the drainage will first begin to be felt at that distance to the left of the boundary-line. From this point the density will begin to fall gradually until the boundary is reached, when it must be *exactly one half the original density*. This follows because of the equivalence of the emigration and immigration on the two sides. Next, as we proceed from the boundary into the drained country, the density continues to fall, until at a distance L on the right of the line, it becomes zero, the country now becoming entirely free of mosquitoes because they can no longer penetrate so far from the undrained country.

In the diagram the line giving the mosquito-density falls very slowly at first, and then, near the boundary, very rapidly, subsequently sinking slowly to zero. The mathematical analysis on which this curve is based is too complex to be given here; but it is not difficult to see that the centripetal law of random migration must determine some such curvature. The mosquitoes which are bred in the pools lying along the boundary-line must remain for the most part in its proximity, only a few finding their way further into the drained country, and only a very few reaching, or nearly reaching, the limit of migration. Though an infinitesimal proportion of them may wander as far as ten, twenty, or more miles into the drained country (and we do not know exactly how far they may not occasionally wander) the vast bulk of the immigrants must remain comparatively close to the boundary. And as, for the reason just given, the mosquito-density on the boundary itself must always be only one half the original density, it follows that it must become very rapidly still less, the further we proceed into the drained country. In fact, the analysis shows that the total number of emigrants must be insignificant when compared with the number of insects which remain behind — that is, when they are not drawn particularly in one direction. We are, therefore, justified in concluding that, as a general rule, the number of immigrants into any area of operations must, for practical purposes, be very small or inappreciable a short distance within the boundary-line. The following diagram probably represents with accuracy the effects of thorough suppression of propagation within a circular area.

At the circle (*a*) and beyond it the mosquito-density will be the normal density which existed before the operations were commenced. At (*b*), the circle bounding the drainage operations, the density will always be about half the normal density. At the circle (*c*) and within it, the density will be small, inappreciable, or zero. The distance from (*a*) to (*b*) may be taken as being the same as that from (*b*) to (*c*); and, as the mosquitoes penetrating from (*b*) to (*c*) must be drawn from the zone between (*a*) and (*b*), the *average* result will be the same as if no immigration at all takes place. We do not possess sufficient data to enable us to calculate the actual distance between (*a*), (*b*), and (*c*) — this will depend in a certain measure on the activity of the species of insect concerned and on the existence or absence of special local attractions; but this fact does not discredit the general principles involved.

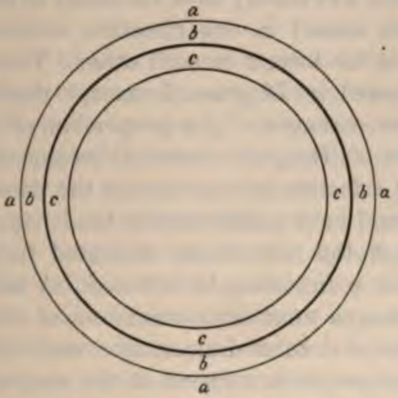

DIAGRAM III. Effect of drainage of a circular area. b = boundary of drained area. Mosquito-density begins to diminish at the circle a; becomes one half at the boundary b; and is small, inappreciable, or zero at the circle c.

One case has not yet been considered, namely, that in which there exists only a single feeding-place in the whole tract of country — such, for instance, as a single house or group of houses situated in the midst of deserted swamps. In such a case the insects may be compelled to come from considerable distances — from as far as their senses are capable of guiding them — in search of food; and drainage operations carried on with a view to relieving such a house may, for all we know, have to be extended over miles. But such cases are not of great consequence, because drainage is seldom the appropriate measure for isolated dwellings, which can generally be protected at far less cost by means of gauze screens. Moreover, it is very doubtful whether feeding-places for mosquitoes are ever so solitary as the case assumes. Where there is one dwelling there are generally many, scattered at various distances over the country; and the insects are known to feed on cattle, birds, and other animals. For towns, where anti-mosquito measures are most demanded, our first assumed condition of uniform attractiveness must, as a rule, be the one in force; and in such cases the centripetal law will hold.

The effect of wind requires examination. Theoretically, if the insects are supposed always to remain on the wing, wind blowing on a generating-pool will merely have the effect of drifting the whole brood to a certain extent in one direction without changing the *relative* positions of the insects to each other. The result would be the same as indicated in Diagram I, except that the generating-pool would now be eccentric. If a proportion of the insects take shelter, the circles of Diagram I would become ellipses with the generating-pool as a focus. In such a case the wind, and especially devious winds, would have a distributive tendency; but it must be remembered that if the insects are scattered further apart their numbers at a given point must be reduced. A wind which blows mosquitoes into an area must blow others out of it. The net result of devious winds on a circular drained area would be that the mosquito-density is not so much reduced at the centre, but is reduced to a greater distance outside the boundary circle — so that the average reduction remains the same. With a wind blowing continuously from one direction, the indication would be to extend the drainage further in that direction. Obviously, wind may scatter mosquitoes; but it cannot create them, nor prevent the total average reduction due to anti-propagation measures, as some people seem to think. It is, however, very doubtful whether wind does really drive or scatter mosquitoes to any great degree. In my experience they are extremely tenacious of locality. Thus *Anopheles* were seldom seen on Tower Hill, a low open hill in the middle of Freetown, Sierra Leone, although numerous generating-pools existed a few hundred yards from the top, all around the foot of it, and the winds were often very strong. If a continuous wind can drive mosquitoes before it, then during the southwest monsoon in India they should be driven away from the west coast and massed towards the east coast; but I have never heard that they are at all less numerous on the west coast. I have often seen very numerous mosquitoes on bare coasts exposed to strong sea-breezes, as at Madras. As a rule, they seem to take shelter in the presence of a strong breeze. Instances of their being driven far by winds are frequently quoted, but in my opinion they were more probably bred, in many such cases, in unobserved pools close at hand. The wind-hypothesis is frequently used by municipal officials as an excuse for doing nothing — it is convenient to blame a marsh miles distant for propagating the mosquitoes which are really produced by faulty sanitation in the town itself.

Another and similar statement is often made with all gravity to the effect that mosquitoes are brought into towns in trains, carts, and cabs. So they are; but a moment's reflection will assure us that the number introduced in this manner must always be infinitesimal compared with those that fly in or which are bred in the town itself. Moreover, if vehicles may bring them in they may also take them out.

I will now endeavor to sum up the arguments which I have laid before you — I fear very cursorily and inadequately. First, I suggested that there must be for every living unit a certain distance which that unit may possibly cover if it continues to move all its life, with such capacity for movement as nature has given it, always in the same direction. I called this distance the limit of migration. It should perhaps be called the ideal limit of migration, because scarcely one in many billions of living units is ever likely to reach it — not because the units do not possess the capacity for covering the distance, but because the laws of chance ordain that they shall scarcely ever continue to move always in the same direction. Next I endeavored to show that, owing to the constant changes of direction which must take place in all random migration, the large majority of units must tend to remain in or near the neighborhood where they were born. Thus, though they may really possess the power to wander much further away, right up to the ideal limit, yet actually they always find themselves confined by the impalpable but no less impassable walls of chance within a much more circumscribed area, which we may call the practical limit of migration — that is, a limit beyond which any given percentage of units which we like to select do not generally pass. Lastly, I tried to apply this reasoning to the important particular case of the immigration of mosquitoes into an area in which their propagation has been arrested by drainage and other suitable means. My conclusions are:

(1) The mosquito-density will always be reduced, not only within the area of operations, but to a distance equal to the ideal limit of migration beyond it.

(2) On the boundary of operations the mosquito-density should always be reduced to about one half the normal density.

(3) The curve of density will rise rapidly outside the boundary and will fall rapidly inside it.

(4) As immigration into an area of operations must always be at the expense of the mosquito population immediately outside it, the average density of the whole area affected by the operations must be the same as if no immigration at all has taken place.

(5) As a general rule for practical purposes, if the area of operations be of any considerable size, immigration will not very materially affect the result.

In conclusion, it must be repeated that the whole subject of mosquito-reduction cannot be scientifically examined without mathematical analysis. The subject is really a part of the mathematical theory of migration — a theory which, so far as I know, has not yet been discussed. It is not possible to make satisfactory experiments on the influx, efflux, and varying density of mosquitoes without such an analysis — and one, I may add, far more minute than has been attempted here. The subject has suffered much at the hands of those who have attempted ill-devised experiments without adequate preliminary consideration, and whose opinions or results have seriously impeded the obviously useful and practical sanitary policy referred to. The statement, so frequently made, that local anti-propagation measures must always be useless, owing to immigration from outside, is equivalent to saying that the population of the United States would remain the same, even if the birth rate were to be reduced to zero. In a recent experiment at Mian Mir in India the astounding result was obtained that the mosquito-density was, if anything, increased by the anti-propagation measures — which is equivalent to saying that the population of the United States would be increased by the abolition of the birth-rate. In the mean time, I for one must continue to believe the somewhat self-evident theory that anti-propagation measures must always reduce the mosquito-density — even if the results at Havana, Ismailia, Klang, Port Swettenham, and other places are not accepted as irrefragable experimental proof of it.

SECTION C—PATHOLOGY

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(*Hall* 13, *September* 22, 10 *a. m.*)

CHAIRMAN: PROFESSOR SIMON FLEXNER, Director of the Rockefeller Institute.
SPEAKERS: PROFESSOR LUDVIG HEKTOEN, University of Chicago.
PROFESSOR JOHANNES ORTH, University of Berlin.
PROFESSOR SHIBASABURO KITASTO, University of Tokio.
SECRETARY: DR. W. McN. MILLER, University of Missouri.

THE RELATIONS OF PATHOLOGY

BY LUDVIG HEKTOEN

[**Ludvig Hektoen,** Professor and Head of Department of Pathology and Bacteriology, University of Chicago, Director of Memorial Institute for Infectious Diseases. **b.** July 2, 1863, Wisconsin. A.B. Luther College, 1883; A.M. 1902; M.D. College of Physicians and Surgeons, Chicago, 1887; Post-graduate, Upsala, Berlin, and Prague. Pathologist, Cook County Hospital, Chicago, 1890–1904; Physician to Coroner's Office, Cook County, 1890–94. **Co-editor,** *Journal of Infectious Diseases*, etc.]

OSTWALD, the inspiring interpreter of the great principles of science, states that "We have just passed through a period in which all sciences have been isolated, a period of specialization, and we find ourselves in an epoch in which the synthetic factors in science are gaining a constantly increasing significance. . . . Everywhere the individual sciences seek points of contact with one another; everywhere the investigator determines the value which his special results may have in the solving of the general problems. In short, all sciences are tending to be philosophical. Nowhere is this tendency toward fundamental explanation so great as in biology."

Pathology a Division of Biology

Disease is the common lot of all forms of life, high as well as low, animal as well as vegetable, and it is the special province of pathology, the science of disease, to study life in its abnormal forms and activities. Hence pathology is a division of biology, and it is in fact pathological biology, but its relationships as such have not always been so clearly appreciated as they ought to be; in part this may be explained on account of the very special stress placed on its direct application to practical medicine in the service of the art of healing. For this and other reasons pathology in many respects has remained somewhat isolated among biological sciences. The early pathologists took the almost exclusive standpoint of human medicine and for a long time the vast resources of general biology remained practically unused in the study of disease. On the other hand, owing to lack of appreciation of the fact that disease is a phenomenon of life, in other words, owing to the unnatural separation of the biologic study of disease from general biology, the subject of disease has rather repelled the average student of biology, who therefore seems to have neglected to utilize fully the approaches offered by pathology to a better knowledge of the phenomena of life.

In view of the extent to which man has busied himself with the study of all forms of animal life in all accessible parts of the world, is it not rather strange and an evidence of lack of coördination that the occurrence of cancer throughout the whole vertebrate kingdom should have been made out definitely only during the last year? Yet this demonstration by the Cancer Research Fund in London, and the further demonstration that cancer has the same fundamental characters as in man when it occurs in fish, reptile, and bird, renders it extremely improbable that either climate or diet of man has anything to do with the direct causation of cancer, thus putting an end to much needless speculation and materially narrowing the scope of a most important inquiry.

Pathological Processes in Evolution

In some quarters disease has been regarded merely as an expression of inferiority and weakness, and as part at least of the means by which inexorable nature carries out the verdict of extermination. Parasitism for instance has been designated as a weapon to eliminate those who fall below a certain standard. Consideration of the nature of disease from this point of view gives to disease merely a negative evolutional significance, as it would cause no new and better qualities in the descendency. Closer examination would tend to show, however, that processes of disease may have a different significance of a more positive nature in evolution. There are numerous simple as well as complex physiological processes which, when set in motion by abnormal conditions, appear to be of advantage not only to the individual but also to the species. As examples of adaptive processes at first sight of more special individual advantage may be mentioned regeneration, hypertrophy, the interesting adaptations to new and strange conditions of which bones and vessels are capable, certain phases of thrombosis, and even atrophy, which has been described as the faculty of an organ to adapt itself to conditions of diminished nutrition, thus circumventing necrosis, a faculty of great advantage when the period of diminished food-supply is only temporary. No one can fail to see much that must be useful and advantageous in the complex reactions to injuries observed in inflammations, the significance of which has been greatly broadened through the well-known comparative study of Metchnikoff. In the case of immunity, natural and acquired, our wonder knows no bounds, so marvelous are the precision and scope of the protective reactions, concerning which so much has been brought to light in recent years and which lend themselves well to comparative studies. In the case of degenerations and tumors it is not possible to recognize any direct or indirect advantage, and certainly no one has yet been able to see malignant tumors in such favorable light. In these instances first mentioned the pathologic reactions have physiologic prototypes; they are adaptations of physiologic processes. Regeneration and growth are taking place constantly in health. Phagocytosis, on which so much stress has been laid in inflammation, is merely an exaggeration of normal nutritive processes in certain cells. At present the production of antitoxins and other anti-bodies is best explained as the result of special adaptations of normal stereo-chemical mechanisms whereby nutrition is carried on. A very noticeable difference between the physiologic and pathologic manifestations of these functions is seen in their imperfections and shortcomings under many of the abnormal conditions. Incomplete regeneration resulting in the formation of scars often has many disadvantages. Inflammations frequently establish conditions in themselves fraught with dangers. The reactions of immunity may not neutralize quickly enough the toxins nor destroy promptly enough the invading organisms. Hence there is abundant scope for the intervention of the physician armed with all the various appliances of his art, some of the most useful of which are the products of artificially produced biologic reactions. But after all the individual organisms must enjoy the best chances for survival and reproduction that suffer least harm because best able to adapt themselves and to protect the life and function of their cells under conditions of disease.

Just as there are variations in the limits of physiologic regulatory mechanisms, so also there are individual differences of degree in the power of adaptive and protective reactions to establish themselves in disease and permit continuance of life. In progressive evolution it naturally must be in the descendants of individuals with the best adaptive and protective powers that an increasing completeness and perfection of such powers will be found. Viewed in this light many processes of disease assume a significance of positive character in biologic evolution, a point of view that would increase the interest in pathology among biologists in general, and thus tend to further its development along broader lines and lead to coördination of knowledge and broad and still broader generalizations as to causes, nature, and processes of disease. At present we may be said to be gathering materials for this broader comparative pathological biology of the future in the same way as the older naturalists gathered materials for the biologist of the present day.

Pathology and Research

At least in certain fields the student of the pure science of disease is primarily interested in the knowledge of disease for its own sake without much thought or immediate care as to any prompt practical use to which such contributions as he may make to this knowledge may be put. It is true here as it is in general that most things are done only on account of the results expected from them in the future, but immediate technical utility is not always the sole guiding principle of the investigator in pathologic domains. The history of pathology shows him that in this science as well as in its synthetic sciences all actual increase in knowledge eventually helps to relieve suffering. Everywhere the most intimate relations may be seen between the progress of medical knowledge and the progress of medical art. Like other sciences pathology furnishes many examples of the rather unexpected importance and the even profound influence of the new observation, the new methods of study, the new point of view that at first seemed to have but limited significance. Indeed some of the fundamental ideas of scientific medicine have arisen in this way. It has been well said that no knowledge of substance or force or life is so remote or minute, but that to-morrow it may become an indispensable need (van Hise). We in America have therefore much reason to rejoice because of the strong movement that is starting in the interest of scholarship and of research in pathology, a movement that of course does not limit its influence merely to the advancement of knowledge, but exercises as well a powerful influence upon the diffusion of knowledge. The man who is so full of enthusiasm for pathology that he will "burn his lamp for its advancement" is likely also to be an inspiring teacher illuminating the older knowledge with the discovery of to-day and placing the new facts in their proper relations to what is already known and to what will be known. Medicine in this country has been so preoccupied with building-up medical education for the training of physicians that comparatively little energy has been available for the upbuilding of medical science itself. Thus pathology in the universities has not been taught until very recently in such a way that graduate students might take it up as a branch to be followed through long stretches of labor. This is regrettable, but in some of our universities pathology is now placed on equal footing with other natural sciences and fully recognized as a proper field for work leading to higher degrees, and this is a much desired progress in a most important direction. The direct interest now taken by many persons in medical research, the institutes and funds their munificence has established, are also having a most profound influence upon the development of pathology in this country. Another mighty current in favor of this development has set in from the scientific work carried on in our various governmental and state institutions.

Pathology and Synthetic Sciences

Let us now attempt to trace briefly the present relations of pathology to cognate sciences with the object of learning, if possible, in which direction the hope lies for greatest progress and to mark out the paths along which our investigators must journey in order to gather the best materials for that wider and larger pathological biology upon which we are still to work. The clearest conception of the rôle that the more important synthetic factors have had and are having upon the development of pathology will be obtained through the historical perspective. In this way, too, it may prove feasible to show how some of the special problems have been solved and to bring into relief the great coördination of useful knowledge exemplified by practical medicine and the influence upon it that various sciences have had and are having through the medium of pathology.

The Anatomical Idea in Medicine

Anatomy was one of the earliest biological sciences to receive cultivation. The first laboratory for the training of students was the anatomical. One cause at least for this, if not the cause, was the downright necessity for physicians to become closely acquainted with the structure as well as the functions of the human body. It is consequently not strange that pathology in the usual modern sense should begin as pathological anatomy, that is with the study of the grosser, evident alterations in structure that result from disease and upon which in turn rest many of the disturbances of function observed in disease. In its earlier stages pathological anatomy busied itself with the accumulation of a store of facts and observations gained almost wholly by the examination of human bodies after death. Morgagni was the first to attempt any generalization from this store of facts and by correlating the anatomical changes observed after death with the disturbances of functions observed as clinical symptoms during life, he was able to draw conclusions of fundamental importance in regard to the seats and causes, at least in certain phases, of disease. This is the first instance of synthesis on a large scale of two biological sciences in the study of pathology, namely the physiological or study of function and the anatomical or study of structure. Morgagni's conception of disease as inseparably connected with structural changes in the organs was designated happily by Virchow as the anatomical idea in medicine, and this idea — the greatest gift of anatomy to medicine — proved of incalculable service in turning the minds of physicians away from speculation to careful, objective study of disease during life as well as after death. We catch an interesting glimpse of Morgagni's own point of view in the following quotation from his writings: "The various steps in progress ought not to be disregarded, for, in difficult research, we derive encouragement from the recollection that although the exertions of an individual may not advance philosophy in any perceptible degree, yet, owing to the power of experiment and the successive influence of opinion, the most obscure and apparently unsuccessful inquirer may prove the first or the connecting link in a series of most valuable discoveries."

The Cell Doctrine

The next advance was the result of Bichat's introduction of minute anatomy and the demonstration that the organs consist of tissues to which the seat of disease now was referred. Before long came the epochal development in botany under the influence of Schleiden of the cell doctrine, which was applied by Schwann to normal animal histology, and by Virchow in 1858 to pathology, the direct outgrowth being the justly celebrated cellular pathology beginning an era during which medicine has made greater progress than in all preceding time.

Physiological and pathological processes were traced to the elementary morphologic constituents of living organisms — the cells. The famous phrase "*omnis cellula e cellula*" completed the liberation of medicine from abstract speculation already begun by Morgagni. "The physician grew from a schoolman into a scientific observer, and the surgeon, who appeared on the scene in livery and without learning, grew from a handicraftsman to be a man of science." Pathology became a natural science. What rich new fields were now open for investigation! A vast amount of material was accumulated from careful clinical and morphologic study of individual cases and the basis thus laid for the construction of general laws and fruitful theories of disease. During the earlier part of this period attention was confined largely to man, but it also was often turned in the direction of animals in the effort to penetrate deeper into morbid processes; the experimental method was used to interpret correctly observations made in the clinic and in the post-mortem room.

Of fundamental importance for all branches of medicine was the resulting organization of the teaching and investigation of pathological anatomy. Following the leadership of Virchow in Berlin pathologico-anatomical institutes or laboratories were rapidly established, and soon recognized as indispensably necessary for teaching, for research, and for direct assistance to medical practice. In the further course of development these laboratories have undergone various modifications and enlargements of scope, principally as the result of the advent of medical microbiology.

With surgery and the rapidly developing surgical specialties pathological anatomy — gross and microscopic — soon assumed permanent relations of fundamental character. The anatomical study of the diseases in question was followed by great progress in treatment, and the exponents of these branches of applied medicine did not remain merely receptive of the work of others, but have themselves prosecuted diligently pathological investigations of great value. Indeed, in certain special branches, especially ophthalmology, otology, and dermatology, the clinicians have long been practically the sole occupants of the field of pathological anatomy of their respective parts of the body. The close study of pathological anatomy — being largely the study of the results of disease — stimulated also to brilliantly accurate diagnosis of certain internal diseases, which unfortunately in some cases was coupled with a disheartening therapeutic pessimism. Said the therapeutic nihilist Skoda: "We can diagnose disease, describe it, and get a grasp of it, but we dare not by any means expect to cure it." That some of the followers of cellular pathology in the narrower, dogmatic sense, believed that the innermost secrets of disease could be reached by morphologic methods, and that functional disturbances always could be adequately explained by morphologic means may now be regarded as an instance of the tendency man frequently shows to approach his problems from the least accessible points. These unfavorable tendencies in pathology led to the following protest by Clark in 1884:

"We are so much concerned with anatomical changes; we have given so much time to their evolutions, differentiations, and relations; we are so much dominated by the idea that in dealing with them we are dealing with disease itself that we have overlooked the fundamental truth that these anatomical changes are but secondary and sometimes the least important expressions or manifestations of states which underlie them. It is to these dynamic states that our thoughts and energies should be turned; they precede, underlie, and originate structural changes; they determine their character, course, and issues; in them is the secret of disease, and if our control of it is ever to become greater and better, it is upon them that our experiments must be made."

Fortunately Clark's warning had been anticipated by development. Virchow himself long before repeatedly emphasized that pathological anatomy cannot deal forever with the product without searching for the cause that led to its production. It seems to me that the following highly remarkable statement in the Prospectus of the first volume of Virchow's *Archiv*, published in 1847, shows that the founder of cellular pathology had a wonderfully clear vision of the rôle pathological anatomy was to play in the evolution of pathological physiology:

"The standpoint we aim to occupy is simply that of natural science. Practical medicine, the applied theoretical, the theoretical-pathological physiology is the ideal we shall strive to reach so far as our powers permit. While we recognize fully the title and the independence of pathological anatomy, and of the clinic, they serve us preëminently as sources of new questions the answers to which fall to the lot of pathological physiology. Inasmuch, however, as these questions to a large extent may be formulated only through painstaking and comprehensive detailed study of manifestations (of disease) in the living, and of the conditions in the dead, we regard the exact growth of anatomical and clinical experiences as the first and most important demand of the present time. From an empiricism of this kind will result gradually the true theory of medicine, pathological physiology!"

Microbiology, Etiology, Comparative Pathology

It was reserved for etiology, the offspring of microbiology, "to lift pathology permanently out of the level of a purely descriptive science, for with the entrance of a dynamic factor, a causal element, under the guise of microörganisms, the experimental era began definitely."

The coming of microbiology, long foreshadowed by ingenious speculations concerning infectious diseases, at once made pathology broader and definitely comparative in its scope, thus widening its relations to general biology on the one hand, and to preventive and curative medicine on the other. It will be recalled that the founders of bacteriology — Pasteur, chemist and biologist, and Koch, physician — both made their appearance in medicine as investigators of animal infections. Infectious diseases constitute a prominent part in the field of pathology, and deeper insight into their nature required simple, easily controllable conditions accessible to experiment and analysis. This became possible by the discovery and study of microörganisms which could be used to set in motion the complex phenomena of disease according to the pleasure of the investigator. In animals the course of a disease may be cut short at any time for the purpose of investigation and better insight obtained into the evolutions of morbid processes. The disease may be studied in all its phases. Hence comparative pathology rapidly became the refuge of the investigator finding his way blocked by the necessary restrictions governing the study of human diseases. The great influence of the comparative method of study of infectious diseases is well shown in the relatively advanced state of our knowledge in regard to those human diseases of this class that are readily communicable to animals as compared with our ignorance in regard to the cause of certain other human diseases which so far as we know are not transferable to animals.

As the secrets of the vast domain of parasitism were revealed, and the teachings of specific etiology and pathogenesis became appreciated, there sprang up in the place of the therapeutic hopelessness inspired by the study of pathological anatomy only, an increasing interest of enormous consequences in preventive measures. This was the natural outcome of the persistent efforts now made to follow the chain of causation so far as it was possible to go; for it early became established that the farther back of the immediate causes of diseases we can come the more easily and economically are they controlled and, reversely, the nearer we approach the period in the evolution of disease characterized by open manifestations the more difficult is disease to overcome. Hence the newer ideas of cleanliness, of surgical asepsis, sanitary science, and preventive medicine, — all are the offspring of the study of microbiology and etiology in a wide sense. Indeed, the great principle of prevention may be applied with perfect success even when the actual cause of the disease remains unknown. The discovery by Walter Reed, for instance, that the cause of yellow fever is conveyed by a certain kind of mosquito makes it possible to prevent this destructive disease with absolute certainty by destroying the mosquito or preventing its bite.

Interaction of Parasite and Host — Bio-chemistry and Immunity.

But the fundamental problems of etiology are not wholly solved by the discovery of the causative agent, however important this step may be; for it remains to explain how normal function and structure are upset by the entrance of this new factor.

Now the study of bacteriology and comparative pathology has permitted a deeper penetration into the nature and mechanism of certain infections. The discovery of bacterial and other toxins, complex, soluble, and diffusible chemical substances, and of their wonderful influence upon the metabolism of cells, opened new and rich fields that under the hands of keen investigators have furnished precious materials for the advancement of medical science along new lines. Henle had anticipated many of our ideas of the interaction of parasite and host, but especially interesting are the teachings of Bretonneau in regard to the specificness of infectious processes, and the words of his pupil, the great Trousseau, have proved themselves of prophetic significance: "There are [in infectious diseases] two factors; one is the morbific germ coming from without, and the other is the economy about to receive it; there is required a special aptitude for the organism to respond to the action of the stimulus . . . when there is no such predisposition the morbific germ perishes." It was necessary to erect the great structure of cellular pathology, and to make brilliant and epochal discoveries in morbific etiology before the suggestions in Trousseau's statement as to the interaction of host and parasite could be expressed in such definite terms, and given such enlargement in scope as in the genial and heuristic side-chain theory of Ehrlich. According to this theory a toxin is poisonous only when it unites chemically with some constituent in the cell of corresponding stereochemical configuration. If the cell does not contain this particular constituent the toxin is harmless; and when these constituents course in the blood as the result of reproductive processes in the cells they are protective — antitoxic — because they unite with the toxin and thus prevent the disastrous union of toxin with cells. In other words, the substance in the body which, when situated in the cells, is a primary essential for the toxic process, becomes a curative agent when it enters the blood-stream (Behring).

Fortunately for the therapy and prevention of diphtheria, tetanus, and a few other essentially toxic infections, these antitoxins may be caused to accumulate in large quantities in the blood of certain animals when artificially immunized by the injection of increasing doses of the corresponding toxin. It was a happy inspiration indeed that led Behring to use the antitoxic serum of immunized animals for curative and prophylactic purposes, thus turning to the common good this innate faculty of the animal organism to develop in so marvelous a manner its own resources.

Supported by numerous experiments among the most imaginative and interesting of modern biologic investigation, Ehrlich's theory has proven a veritable master-key to some of the innermost secrets of toxic and antitoxic action and immunity in general. The theory has been found adaptable to other closely related problems in chemical biology, and its signal usefulness in promoting investigation in this complex field upon broad comparative basis places it among the great theories of science.

Ehrlich's side-chain theory has been applied with great success to the explanation of the formation by cells, and also of the action of the various lytic or solvent substances for animal cells, particularly red corpuscles, as well as for bacteria. The active hemolysins, bacteriolysins, and cytolysins are formed by the union of two distinct bodies, amboceptor and complement, whose properties and affinities are being studied most actively. These substances occur to a considerable extent in the blood of normal animals, and may be induced to develop freely under the stimulation of the injection into animals of large quantities of the cells or bacteria to be acted upon. The fact that hemolytic substances, though of a somewhat different and apparently less complex nature are produced by certain pathogenic bacteria of common occurrence, especially streptococci, has given us a new point of departure for the study of the anemia that develops in streptococcal and other infections. By the aid of Ehrlich's theory it has also proved possible to explain the mode of action of the toxic substances in certain venoms, and in this particular field highly valuable facts have been established by the work of Flexner and Noguchi and of Kyes. In certain phases the subject has been simplified by the work of Kyes, who succeeded in showing that a definite chemical substance, namely, lecithin, may act as a complement to amboceptors in venoms, with which it unites as a crystallizable "lecithid."

The extraordinary complexity of the chemical bodies produced by cellular activity is further illustrated by the group of substances known as agglutinins which have the interesting property of drawing animal as well as bacterial cells together into clumps. Agglutinins may be produced by bacteria as well as by animals. It is more than likely that certain forms of thrombosis met with in infections are caused by agglutination of corpuscles, a form of thrombosis which has been designated as agglutinative. Experimentally such thrombi are produced with ease by the injection of various agglutinating substances. In animals as well as in man certain infections, *e. g.*, with typhoid bacillus, are associated with the development of agglutinins having a specific effect upon the bacterium causing the infection. Such agglutinins are being used everywhere for two purposes, (*a*) to determine the nature of the infection for purposes of clinical diagnosis (as in the agglutination test for typhoid introduced as a clinical measure by Grünbaum) and (*b*) to identify certain bacteria and establish their relations to the infection.

Another interesting group of substances of the same general class is formed by the coagulins which have the power of causing certain changes in colloidal albuminous solutions.

Furthermore it has been found that the serum of an animal treated with a proteid forms precipitates with that one proteid, a property that within certain limits appears to be specific. This has led to the use of specially prepared precipitating serums for the diagnosis of different proteids, *e. g.*, the detection of human blood for medicolegal purposes, and for the study of the genetic relationships of certain animals, a study that in the hands of Nuttall has given results of general chemico-biological interest from an evolutional point of view.

Reviewing these remarkable developments one is profoundly impressed with the fact that at the same time as they constitute a most important widening-out of biochemical science they have added greatly indeed to the permanent resources of practical medicine, emphasizing again in the clearest way the everlasting identity of the scientific and the practical. Let no one, at least in the medical profession, ever doubt the practical value of the knowledge that ripens on the tree of science! These developments also demonstrate that there are other modes of progress toward knowledge of cellular activity and biological mechanisms under pathological as well as normal conditions than the purely morphologic highway which hitherto had been followed with great persistence in pathology.

Here we are dealing with chemical substances and chemical and physical processes which ultimately will be interpreted in terms of chemistry and physics. Already Arrhenius and Madsen have attempted to show that the laws of mass-action and chemical equilibrium govern the reactions between toxin and antitoxin, an attempt that has precipitated a sharp controversy with the Ehrlich school which cannot but powerfully stimulate continued work in this field. Recently we have learned too that many salts in ionizable solutions and also more complex substances combine in such a way with the complements in normal and immune serums as to hinder the union of complement and amboceptor necessary for lytic action. Perchance it is in this direction that we may look for some insight into the changes in physiological mechanisms that permit various organisms to enter and set up disease.

It seems that in the chemistry of immunity we soon may expect most interesting developments. The fact that lecithin may act as complement, that it forms a crystallizable "lecithid" by union with the hemolytic amboceptor of snake-venom, and further, the evidence now at hand that colloidal silicic acid may play the part of amboceptor, warrant the hope that before long complete analysis, and perhaps even synthesis, of lysins may become possible.

The Synthesis of Different Methods in Scientific and Practical Medicine

In the majority of cases we owe our first knowledge of the existence of distinct diseases to clinical observation. By keen study physicians were able to distinguish even between more or less similar pictures, but the clinical picture has not always proved adequate for the determination of disease-entities. The clinical manifestations of certain diseases are so much alike that differentiation finally was accomplished as the result largely of the study of the more or less characteristic structural changes in the tissues of the body. In some cases differentiation could be made only after the discovery of the specific causative organism. This was the case with diphtheria. The clinical manifestations and the local anatomical changes in the throat caused by the bacillus of diphtheria may be reproduced in streptococcal and other infections. Now it is self-evident that real penetration into the nature of a disease demands its complete separation from other, in certian respects more or less similar, diseases. In the case of diphtheria, for instance, complete etiologic differentiation was essential in order that the real value of diphtheria antitoxin might be learned. It may be mentioned, too, that it required the discovery by Koch of the same bacillus in practically all forms of human tuberculosis before the doctrine of the dual nature of this disease, at one time advocated by Virchow on anatomic grounds, received its final overthrow.

In various local inflammatory diseases such as pleuritis, pericarditis, peritonitis, meningitis, and in many so-called septic conditions, *i. e.*, local infections with general intoxication but with or without bacteremia, the same clinical manifestations and anatomical changes may be produced by different organisms. The diseases being different etiologically are consequently also in all likelihood different chemically in spite of their clinical and anatomical similarities, and for these reasons deeper penetration into their nature as well as progress in direct treatment will depend largely on study of the organisms concerned and of the products of their activities. Clearly an essential step in this direction is the differentiation of the diseases on etiologic grounds. Other examples of analogous nature could easily be cited.

Now, practically every disease the nature of which we in some degree understand may be cited in illustration of the close synthesis of clinical observation (clinical pathological physiology), pathological morphology, etiology, and microbiology, experimental and comparative methods, and especially more recently of chemistry in the development of our knowledge of disease. To the fullest extent this is true of certain infectious diseases. Starting with normal physiology and anatomy, these have become the principal methods by which material is accumulated for that pathological physiology which Virchow put as the chief end of medical investigation. And it is along this road too that the medical student passes to reach membership in the medical profession; for here also "ontogeny repeats phylogeny." Finally these are also the very methods of procedure employed by the true physician in solving the problems of diagnosis and so of treatment presented by the individual patient no matter to what specialty the case may be referred in consequence of the great differentiation of medical art with which we are familiar.

Practical medicine is availing itself more and more of the methods of scientific medicine. The laboratory is entering into closer and closer relations with the clinic. For the purpose of facilitating investigation as well as treatment it has been found advantageous to include various laboratories in the clinic, and the use of laboratory methods has extended to all departments of medical practice where their field of usefulness is constantly enlarging. How these methods may be made most easily available for the practitioner has now become a problem of real urgency. Pathology is consequently a great force in the interests of integration as opposed to differentiation in medicine; for pathology gathers under her wings all the specialties which differ not as to methods but only in the matter of the fields investigated.

Whatever the rôle of pure morphology in the investigations of fundamental biological problems — and it does not seem likely that it will lose greatly in significance in this respect so long as biologists regard the peculiar complexus of physical conditions called structure as absolutely essential to life — it always will maintain relations of fundamental importance in medicine. Medical and surgical diagnosis rests to a large extent upon the recognition of the nature and cause of gross changes in structure and their consequences on function. To the surgeon pathological anatomy is a guide whose minutest direction he must obey. Exact clinical observation controlled so much as ever possible by anatomical examination will continue, as emphasized always by Chr. Fenger, the mainstay of medical progress in every locality. The value of microscopic anatomy in the study of diseases of the blood, in the differentiation of new growths, and in inflammatory products needs only mention. Many of the methods of microbiology are essentially morphologic. The established classification of bacteria is based on morphology, and the studies of the relations of microörganisms to the cells of the body — often a matter of great importance — requires morphologic methods.

I believe there is no room for the opinion one occasionally hears expressed to the effect that the value of the usual methods of morphology and microbiology in scientific pathologic investigation has been exhausted. Of course the field cannot be said to be so large as at one time, but there are still problems enough demanding the use of these very methods, refinements and improvements in which are constantly increasing their usefulness. Unquestionably advances in our knowledge of functional localization and in the tracing of conduction paths in the central nervous system of man will continue to depend in the main on the careful study of anatomical lesions and their functional and structural consequences. Blastomycosis and paratyphoid fever are brilliant examples of "new diseases" recently established as the result of purely morphologic and microbiologic methods of study in fields long diligently explored. In trypanosomiasis and piroplasmosis of man and of animals we have other examples of interesting diseases for the recent knowledge of the existence of which as etiologic entities we are indebted chiefly to clinical observation and morphologic studies of the blood. These facts indicate that microbic etiology may yet be forced to yield up hitherto carefully guarded secrets to more or less familiar methods of new modifications thereof.

Great interest has been awakened in the recent determined effort by Councilman and his associates to solve by these methods the etiology of variola, the final proof of the success or failure of which must be left to more discriminating forms of microbiologic research.

In pathology purely morphologic methods have surely as great an importance in establishing etiologic relationships and as a means of orientation in various forms of investigation as they have in unraveling the intricate connection between structure and function. Progress in the domains of microscopic pathological morphology and progress in normal morphology will always be mutually helpful because pathological cellular changes — necrosis, necrobiosis, degenerations, and proliferations — are probably largely identical with normal cytomorphosis, being abnormal only as to time and place. A recent morphological observation of great interest is that by Bashford and Murray of a process of conjugation in cancer cells. These observers found in cancer cells nuclear changes similar to those by which sexual cells are prepared for fertilization and also fusion of nuclei equivalent to the process of fertilization known as conjugation. This discovery (if confirmed) will help to turn the search for the causative factor in cancer directly to the very processes in the cells themselves, a direction indicated already by the singular fact that cancer always "breeds true," and that it is transplantable only within the species in which it originates, and that it behaves as an independent organism. Undoubtedly the newer methods of study of micro-chemical reactions in normal cytology will prove valuable also in pathological cytology. Perchance this synthesis of morphological and chemical methods in time may give us some insight into the normal relations and time-sequence of chemical reactions in biological processes, normal as well as abnormal.

It proved to be an auspicious day both for chemistry and medicine when Pasteur conceived his biological theory of alcoholic fermentation. Ludwig's prophecy of forty years ago that chemical physiology would largely prove a study of catalytic reactions has come true, and the cell is now no longer considered as a simple structure, but rather as a most complicated machine, the working of which for the most part is dependent on enzymes. Into the finer details of the manner in which these mechanisms may be disturbed under abnormal conditions we as yet have hardly been permitted to penetrate, but the extensive recent researches dealing with the nature and mode of action of ferments in diverse physiological activities have awakened a lively interest in fermentations in pathological processes which augurs well for the future.

Among the many intracellular ferments those causing self-digestion or autolysis of cells are thought to play an active and essential rôle in the removal of dead material, such as necrotic tissue in infractions and inflammatory exudates. Some idea of the fermentative activities in autolysis may be obtained from its action in pneumonia. In a few days autolysis may so alter a mass of exudate weighing several hundred grams that it is readily removed from the lungs by absorption and expectoration.

The biochemical mechanisms of normal and pathological pigment formation have now been shown to depend on the action of oxidative ferments.

Cohnheim's demonstration that two enzymes, one coming from the pancreas and the other from the muscles, are necessary for the oxidation of sugar, appears to be a long step toward putting the pathogenesis of diabetes in an entirely new light. While these and other oxidizing ferments are the products of cellular activity, it at once suggests itself that they need not be the products of the cells of the same body which is later to use them. It has been suggested that they may be introduced as needed much as antitoxins now are introduced (Long).

The results of the work of Croft Hill and of Kastle and Loewenhardt on the reversibility of ferment action have been eagerly grasped by pathologists and made to throw new light on the problems of fat absorption and translocation. Indeed, the newer chemical methods of study are changing completely our older ideas about fatty changes in the cells, ideas that were based almost wholly upon morphological appearances. Great progress has been made also in other respects in recent years from the application of the methods of physiological chemistry to pathological problems, but I must refrain from going into further details. As a result the field of pure chemistry as an aid to medical diagnosis is enlarging, not merely as regards various analytical procedures for the testing of fluids and other substances, but the newer methods of physical chemistry such as testing the solution content by electrical conductivity and cryoscopy have been found useful in order to obtain information of help in reaching a correct diagnosis or a better understanding of the nature of the functional disturbance.

As indicated in the foregoing we are now at the beginning of an era of the application of newer physical and chemical methods to many problems in medicine, problems that at one time were regarded as approachable only by so-called biological methods, and the number of problems that lend themselves promisingly to this form of treatment seems to be constantly increasing. I have referred already to their use in the study of chemical problems in immunity. The many fundamental problems connected with the constancy of osmotic pressure in the fluids of the body; the great influence of osmotic disturbances in the production of edema; the interesting relations of ions to proteins; the physico-chemical properties of ions of various salts in relation to pharmacological action — these are some of the new questions that are being actively studied with results in many cases of far-reaching importance.

In many of its phases this departure is the outcome of the application by Loeb and others of general chemistry to biological study the results of which we have followed with increasing wonder as they have shown us the extent to which certain life phenomena can be controlled unequivocally by chemical and physical means. Many of the manifestations of life are physical in character, but biologists are agreed that the source of energy in life phenomena is chemical, and that general chemistry therefore must form the foundation of biology. From this it follows directly that the deeper, fundamental explanation of the mechanisms of pathological processes also requires chemical and physical methods. Henceforth chemistry will play an increasingly important rôle in the efforts to reduce the phenomena of pathological biology to simpler laws. We thus find again that sharp lines of demarkation cannot be drawn between normal and pathological biology; for progress in one naturally exercises determining influence on progress in the other, and in both development is in the direction of synthesis with physics and chemistry.

Medicine has been called the mother of sciences, and not without reason. She gave to physics Galileo, Mayer, Helmholtz; to geology Steno; to botany Linnaeus; to chemistry Black, Berzelius, Liebig; to biology Aristoteler, Lamarck, and Huxley; but as pointed out by Sir Michael Foster, her children are ever coming back to help her. In medicine as a science and as an art many sciences converge — physical, chemical, and biological methods join hands for the advancement of knowledge and the relief of suffering.

WORKS OF REFERENCE

Of the various articles from which I have drawn freely in preparing this address I would mention the following especially:

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THE RELATION OF PATHOLOGY TO OTHER SCIENCES

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WHOEVER has to speak of pathology in general, as is my task, must first determine what he includes in pathology, for the ideas which are evoked by this term are not always the same. The opinion is common that pathology is synonymous with "science of disease," "nosology;" but this, as Rudolph Virchow [1] has attempted to prove repeatedly, is not true. Doubtless disease, or rather the diseased individual, is the most important object of consideration of pathology; it is, however, not the only one. The conception of pathology is much more comprehensive. To pathology belongs, on the one hand, every deviation from the normal structure and the normal composition of the body, and, on the other, every deviation from the normal function of its parts. It therefore includes every variation from what we consider the type of an organism. Variation from type is, however, not disease. Disease is, as Boerhaave was the first to say, "*Vita praeter naturam,*" and life presupposes activity. When there is no functional activity and thus no deviation from normal function, there can be no disease. But not even every functional variation from the normal indicates disease. The variation must be pernicious in character, if it is to bear the name of disease. When there is no detriment, there is no disease, although whenever a variation from the normal exists, we have to do with a pathologic condition, no matter whether the variation is morphologic or functional.

Purely morphologic variations without detrimental influence on the rest of the body are found, especially among anomalies and malformations, and who will deny that these belong to the realm of pathology? An individual with a supernumerary nipple, a person with polydactilism, a woman with uterus septus or bicornis, all are pathologic, although none are sick. Thus, while the biologic phenomena of the diseased state form the greater part of the realm of pathology, they do not complete it. Its limits must be extended much further, but how far is the point of contention.

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[1] *Handb. d. spec. Pathol. u. Therapie,* 1854, pp. 6 ff.

Many may consider the statement of Virchow[1] a witty paradox when he says that the development of new species really belongs to the realm of pathology, as a new species must find its origin in a variation or deviation from the preceding type, and variation from type is pathologic. Thus the whole teaching of evolution, the science of phylogeny, is to be considered part of pathology. I share throughout Virchow's opinion, and in my work on inherited and congenital diseases, recently published,[2] I have again given this fact expression that we must presuppose a variability of the embryonal protoplasm (*Keimplasma*) and that variation or deviation from the previous type either acquired or inherited or even arising from external influences is the necessary preliminary to the formation of a new species, subspecies, or variety. I would not, however, like to go so far as to call everything arising in this way pathologic, no more than I can consider it pathologic when, by immunization, a man is made better than he was before. Such a man varies from the type of normal man, but is not pathologic, because the variation is useful and appropriate. Only variation which is inappropriate or useless is pathologic. I realize that it may often be difficult to determine the limits of the inappropriate and useless and thereby pathologic, especially in the development of varieties and races. Thus, I should not hesitate to class the Crested Polish fowl with its exencephalocele as pathologic, while I should exclude those breeds which the animal breeders have made for useful purposes from pathology, no matter how near the pathologic the products of skill might be.

Variations from type occur in inanimate as well as animate nature; there are malformed crystals just as there are malformed plants, animals, and persons, but we are not accustomed to speak of a pathology of crystals or stones, but only of plant, animal, and human pathology, for only with living beings can we rightly speak of useless, inappropriate, or pernicious variations from the normal.

Human pathology, undoubtedly the most momentous and important for us, has made but little use of plant pathology as yet, although there can be no doubt that many conclusions for general pathology as for general anatomy are to be drawn from botany. The reaction of plant cells to unusual conditions, and the morphologic and functional disturbances which occur under such circumstances are easier to observe, and may well serve as guides to the understanding of similar processes in animal or human cells. Experimental pathology has already made use of plants in its investigations,[3] but only recently have we begun to give more attention to the spontaneous diseases of plants, especially since we have learned how great a rôle parasitism plays in vegetable as well as human pathology. At the head of the parasitic problems of human pathology of the present day stands that of the etiology of tumors; here cancer cells, here cancer parasites, so sound the battle-cries, and a parasitic new formation in the vegetable kingdom, the club-root of turnip, did not only have to furnish the paradigma of cancers in man and beast, but some investigators have even gone a step farther and see in *Plasmodiaphora brassicae*, the parasite of club-root, the exciting cause of animal tumors or at least a close relation of such cause.[1]

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[1] R. Virchow, *Rassenbildung u. Erblichkeit, in Festschrift für Batian*, 1896.

[2] Orth, *Angeborene u. ererbte Krankheiten u. Krankheitsanlagen, in Krankheit und Ehe*, herausgegeben von Senator u. Kaminer, München, 1904, p. 26.

[3] O. Israel, *Biolog. Studien mit Rücksicht auf d. Pathol. Virchow's Arch.* 141, p. 209, 1895.

Very different is the relation of human to animal pathology, not only on account of the closer relation between man and animal, by reason of which a comparison of observations between animals, especially the higher vertebrates, and human pathology is more permissible, but also because the questions to be decided experimentally must be proved in the main on animals.

Even though a complete agreement between the phenomena of human and animal pathology cannot exist, as the function and construction of the animal body and its organs do not entirely agree with those of man; even though many diseases which attack man do not occur in animals, still analogies are not wanting and the similiarity is greater the higher the group among the vertebrates to which the animal in question belongs. An especial advantage of comparative animal pathology is that the necessary material is not only easier to obtain than the human, but that particularly by voluntary killing of pathologic animals accurate morphologic investigations can be made at any desired stage and on perfectly fresh tissues free from cadaveric changes. Especially valuable conclusions can be drawn in those diseases, which are common to man and animals, the zoönoses and the anomalies of formation, the simpler ones as well as the monsters in the narrower sense.

A somewhat neglected realm of comparative pathology has recently attracted the attention of pathologists in more and more increasing degree; namely, tumor formation in the lower animals.[2] From their construction we may expect to draw valuable conclusions in regard to the pathology of human tumors, not only in the morphologic but also in the genetic direction. One point especially comes into consideration, which also plays an important part in the utilization of animal pathology in other directions, the possibility of purposeful inoculation experiments from animal to animal.[3]

Unfortunately the great value of experimental research for all branches of pathology[1] is not sufficiently known among the laity, and attempts through governmental interference to lay difficulties in the way of experimental investigation (vivisection as it is called by the laity, scientific animal torture according to its opponents), are constantly being made, not seeing that misuse of it, even if it should occur, is considerably outweighed by its undeniable value. Pathologic anatomy, bacteriology, pathologic chemistry, and above all, pathologic physiology, cannot fulfill their scientific value without animal experiment. A large part of the progress in pathology is bound up with experimental research. Every advance in pathology has sooner or later been of use to man. Could our progress in the pathology of the infectious diseases, and our progress in the prevention and treatment of them, have been made without experimental pathology? The explanation of the origin of tumors must also finally arrive by experimental investigations, and just there it will be of especial value to be able to carry on the experiments on the same kind of animal in which the tumor naturally occurs. If we should succeed in finding a specific, probably parasitic cause, the possibility of demonstrating the pathogenicity of this disease-producer on animals of the same sort is incalculable. But such experiments presuppose exact knowledge of the pathology of the animals experimented upon, that is, comparative pathology, and many discussions of the present day have turned on the point whether changes which were found after the experiment were results of the experiment or chance pathologic findings to which the experiment had no genetic relation. If one does not know what kind of tumors occur in the organs of the animal which he is using for experimental purposes, he will easily fall into the danger of considering new formations as the result of the microörganisms injected by him and will report having produced a tumor when merely a spontaneous new growth existed.

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[1] Gaylord, *Zeitschr. f. Krebsforschung*, I, 1903.

[2] Pick u. Poll, Berlin, Klin. Wochnsechr, 1903, p. 518.

[3] C. O. Fenger, *Experim. Untersuch. über Krebs bei Münsen*, *Abh. f. Bakterio.* xxxiv, p. 28, 1903; Borrel, *Epithél. infectieuses Ann. de l'Inst. Pasteur*, 1903, no. 2.

So far I have considered animals only as passive objects of experimental pathology. I have spoken of animals and plants merely as the most important subjects for comparative pathology. There are, however, much closer relations between pathology and botany and zoölogy. Both these sciences have had increasing importance for pathology, as surer proof was brought that the most important causes of disease belong to the plant and animal kingdoms.

Investigation of the causes of disease, of the different conditions which form the basis of deviations from normal types, belongs as much in the realm of pathology as the study of these deviations and their development itself. The etiology and pathogenesis are a part of pathology, and it is especially through them that pathology has its closest relationship with the other sciences. Mechanics, general and cosmic physics, geology not less than geography, inorganic as well as organic chemistry, social and military history, sociology, and commercial science, etc., must all be considered for the enlightenment of the etiology of disease and the explanation of the appearance of disease, especially in regard to time and place (historic geographic pathology). But above all stand zoölogy and botany, for the most important and most common diseases are produced by living beings, by parasites.

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[1] R. Virchow, *Ueber den Werth des pathologischen Experiments,* Internat. Med. Congress, London, 1887, Berlin, 1899.

It is an old statement in pathology that a parasitic relation exists in disease. For a long time the disease as such was thus personified; it was spoken of as an organism within the organism, a parasite, which as Wunderlich[1] said, was anthroposed or phytomorphosed in every way. To it was ascribed an existence, a growth, limbs and organs, a power of endeavor and of thought, even a sickness, death, and finally a corpse. Pathology has done away with this conception. It is true that we still speak of the disease, of cholera, typhoid fever, pneumonia, etc., and that in practical medicine we still speak of treating this or that disease. A treatment for syphilis, for diphtheria, or some other disease is recommended as if we spoke of something tangible, independent. But all this is only for convenience of expression, and we know very well that what we call a disease is not an entity but only a group of phenomena which have for their basis a common cause. There are really no diseases, but merely sick men, diseased organs, diseased tissues, diseased cells, and it is the cause of these disturbances which brings about the special phenomena which we observe in the diseased part.

This cause may be a parasite. Centuries ago the opinion was occasionally expressed that diseases were caused by living beings, which disturbed the life-processes in the human body. In the middle of the last century the view that there must be *contagium vivum* was victoriously upheld by Henle,[2] but only in the last decades of the nineteenth century was actual proof brought forward that by far the commonest causes of disease are living organisms which live parasitically on or in the human body. The disease is not the parasite, but one parasite or many parasites cause those variations from the normal structure and function of parts of the body which in their entirety we call disease.

By parasitology a close union is made between pathology and the described natural sciences and thus with general biology.

The great biologic question as to the origin of the lowest being is related principally to the human parasites. In spite of the statement of the great English physician Harvey, "*Omne vivum ex ovo*," the doctrine of spontaneous generation, which ruled for thousands of years, had not vanished from science, and in the beginning of the last century natural philosophy treated with preference on the beginning of life, and some are not lacking in our day who believe that they see in the doctrine, that the tissues of our bodies break up in decomposing into small organisms,[1] an expression of the immortality of the life principle.

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[1] Wunderlich, *Hdb. d. Patholog. u. Therap.* I, p. 12, 1852.

[2] Henle, *Hdb. d. Ration. Pathol.* II, 2 p. 457, Braunschweig, 1853.

That the large intestinal worms do not arise from the dirt of the intestinal canal, from saburra, but that for them Harvey's rule holds, has been shown by both zoölogists and pathologists. For the smallest beings we may mention the chemist, L. Pasteur, with the physician, Robert Koch, the former of whom conclusively disproved the spontaneous generation of microörganisms; the latter as the discoverer of the methods which permitted us to ascertain simply and surely the constancy of form of a microörganism and to give incontrovertible proof that in every single microörganism the law of generation was true, not entirely in Harvey's sense, but in the more general form: *Omne vivum e vivo ejusdem generis.*

But it is not only general biology which has been furthered by the parasitology of the physician, but also special biology and the systematic classification of parasitic animals and plants. Just here is plainly shown that pathology cannot in any way be separated from the other natural sciences, as it is not only the receiver which makes practical use of scientific discoveries, but also the producer which by its own effort, and through independent performances furthers science. The modern development of bacteriology, the determination and elaboration of exact methods of investigation, the morphology and biology of bacteria, have not been entirely developed by botanists, but it has been and still is physicians and pathologists who may claim a large part of the results as due to their efforts.

The same relation in working together exists between pathology and zoölogy in regard to the parasitic animals. Here the points of contact of the two sciences are doubled, for on one hand the change of generations of many human parasites, their occurrence in different hosts, as well as the fact that animals may be the simple conveyers of parasites, required the human parasitologist to bring the animal world into the realm of their investigations; on the other hand, the morphology and systematic study of the parasitic animals themselves has been ascertained with considerable assistance from pathologists. In the first class I will only recall the joint work of pathologists and zoölogists on trichinosis.[2] In determining the relation of this disease in pigs and other animals to that in man; malaria and the rôle which anopheles play therein; the recent investigations on the conveyance of plague and other infectious diseases by animals. Names of physicians like Küchenmeister,[1] Davaine,[2] and others have given human parasites their final place in zoölogy. I wish also to call attention to the very recent investigations concerning protozoa as disease-producers, one of the most burning questions of modern pathology, a question of extreme importance, and also of correspondingly great difficulty. Unfortunately, investigations on the parasitic protozoa remain still in their infancy, but even on this question the pathologists of Europe and North America may demand recognition of their zealous work.

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[1] R. Arndt, *Unters. über d. Entschung von Kokken und Bakterien in organischen Substanzen*, Virchow, *Arch.*, 82, p. 119, 1880; A. P. Tokker, *Versuch. einer nauen Bakterienlehre*, 1903.

[2] Zenker, *Arch.* I, p. 90; Leukart, *Unters. üb. Trich. spiral.* 1866, R. Virchow, *Lehre von den Trichinen.*

Closest and most numerous are, of course, the relations of pathology to anatomy and physiology. Just as the study of the normal, typic man is divided into anatomy and pathology with physiologic chemistry, so also is pathology (apart from etiology and pathogenesis) made up of pathologic anatomy and pathologic physiology with pathologic chemistry. Just as health and disease pass imperceptibly into one another, so there can be no sharp line drawn between pathologic and normal anatomy, normal and pathologic physiology. These studies are not different sciences, but branches of the same scientific tree with the same stem, the same roots. Their methods of investigation are mainly the same. Discoveries in one generally mean progress in the others.

The time is not long past when instruction in pathologic anatomy in our universities was in the hands of the professor of normal anatomy, and when men like Joh. Fr. Meckel, Johannes Müller, and others enriched and fostered normal as well as pathologic anatomy. Pathologic anatomy is only conceivable on a basis of normal anatomy, and a glance at the history of medicine shows how every progress in normal anatomy has produced an increase in the knowledge of pathologic anatomy. Only the flourishing of anatomy in the sixteenth century made the development of pathology to a separate science during the ensuing century possible. But here also pathology was not only the receiving but frequently the producing science. Pathologists not only enriched anatomic and histologic methods, but contributed largely to the development of accurate anatomy, the general as well as the special. Who does not think in connection with "general anatomy" of Rudolph Virchow,[3] the man who coined the famous words "*omnis cellula e cellula*" corresponding to Harvey's "*omne vivum ex ovo?*" That saying while resting in great part on pathologic observations, is equally true for pathologic and normal anatomy.

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[1] Küchenmeister, *Die in und an d. Körper d. lebend. Menschen vorkommenden Parasiten*, 1878, 1879, 3. Aufl.

[2] Davaine, *Traité des Entozoaires*, Paris, 1877, 2. Aufl.

[3] *Die Cellularpathologie in ihrer Begründung auf physiologische und pathologische Gewebelehre*, 1. Aufl. 1858; 4. Aufl. 1871.

In connection with special anatomy it will suffice to refer to the progress in the anatomy of the brain, especially to the course of its fibers, in order to show how much pathology has contributed to the knowledge of normal structure. The great progress which the fine brain anatomy made in the last decades of the last century is due in large part to pathologic observations, medical investigations, methods conceived by physicians, and the result of investigations has been brought forward in connected form, especially by medical writers.

The same is true, but even to a higher degree, of physiology, the pathologic branch of which has unfortunately not received the deserved recognition and fostering in every place as a separate science, but which nevertheless has not been neglected by scientific medicine.

A large part of our knowledge of human physiology has been obtained by the observations of functions changed by disease as they appear as symptoms of disease in man or are produced artificially by experiment on animals. Where would the physiology of the brain be, if pathology had not made clear the position of the centres and the course of the tracts from the constantly recurring symptoms and lesions and pathologic experiment had not proved the correctness of the conclusions which were drawn from human observations?

What would general cellular physiology be, if observation of the behavior of cells under varying life conditions had not given us information concerning the processes under normal conditions?[1] Is not general cellular physiology rather a product of cellular pathology? Was it not a pathologist, R. Virchow, who introduced the idea that the cell is the final form element of all vital phenomena, and who arrived at this conclusion not least through pathologic observations?

From the deviations one recognizes most readily the law. There is no problem of general biology which has not received enlightenment and explanation from the experiences of pathology. The doctrine of heredity, to name only a few of these problems, plays no small rôle in pathology, and many cases of pathologic heredity throw a clear light on the subject and nature of heredity in general. The latest discoveries of pathology in the realm of hematology, the doctrine of agglutinins and precipitins, has already led to most valuable revelations respecting the general biologic question of the blood relationship of animals with one another, and of animals with man. The blood of anthropoid apes and man shows similar behaviors, but differs from the blood of other animals.

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[1] Verworn, *Allgemeine Physiologie.*

Especially numerous and close relations exist between pathology and that branch of biology which treats of the development of the human and animal body, and these relations are daily becoming closer and more numerous, as more and more frequently it can be proved or at least made probable, that pathologic phenomena of all kinds form the basis of ontogenetic disturbances of the greatest variation.

An important difference exists between normal and pathologic anatomy, in so far as the genetic consideration plays a much greater rôle in the latter than in the former. Finished conditions form the basis of descriptive anatomy. Pathologic anatomy must always consider phases of development and none of its observations can be understood if their origin cannot be explained and if the original condition and the further development of its changes cannot be determined. The original condition, however, leads more and more frequently back to the time of embryonal development. It is to the eternal merit of Joh. Fr. Meckel,[1] the anatomist and pathologist, of Halle, that he showed for the first time in the case of a malformation of the intestinal diverticulum that the essential part of the variation from the normal consists in this, that a condition which is normal for a certain period of embryonal life, but which should only have a transient existence, is retained and is always recognizable in later stages of development, even though changed by the progressive growth of the part. This demonstration was the more important and valuable, as it treated of a theme which had hitherto been the ground of the most remarkable genetic theories. The apparently planless variation from type was explained as the work of demons or devils or as a freak of creative nature (*lusus naturae*). Now, it was shown for the first time that also in the realm of malformations, order and law governed the process and not arbitrariness and freakishness, and that we must consider the embryonal development of these malformations if we would understand and explain these methodic processes.

Thus was founded the doctrine of imperfect development and growth, and as the basis for the explanation of malformations (*Hemmungs-Missbildungen*) it has been especially fruitful, as the fissures about the face, malformations of the female genitals, and congenital malformations of the heart will show, but that they have not yet closed the list is shown by the recent investigations of cystic kidneys, which have proved these to be due to a checking of the development of the embryonal organs. These examples show that disturbances of embryonal development are not only of importance in causing variations from the type, such as malformations, but also for disease-processes in the narrower sense, which originate most readily in malformed parts or organs. The idea that congenital heart disease was due to endocarditis in fetal life was largely due to the knowledge of the susceptibility of the malformed part to secondary so-called chronic inflammation. This is true not only of the macroscopic conditions like those mentioned, but it also favors the idea that incompleteness in the formation and the later development of a part cause a local disposition to disease. But this is only one side of the relationship between disturbances of development and disease. Another, perhaps even more important, is that which treats of the development of tumors on a basis of disturbance of development. The tumors of undescended testicles, the origin of new formations from displaced adrenal fragments, are as familiar to pathology and as surely established as the occurrence of dermoid cysts, which can only be explained on the basis of the history of development. The well-known theory, according to which all tumors depend on disturbances in embryonal development, still lacks sufficient proof. Both pathologists and embryologists have been successful in showing, however, that one tumor at least, the dermoid of the ovary, only finds a satisfactory explanation in the presence of derivatives of all three embryonal layers, thus indicating a very early disturbance of development.[1] These tumors are closely related to malformations and pass without sharp division into true monstrosities. The study of all malformations, not only those due to impeded development and which no one attempts to deprive pathology of, is not to be separated from the study of normal development, for the origin of malformations goes back to the earliest embryonal period, and not only malformations of the whole body but anomalies of its single parts can only be understood and their origin explained in the light of normal developmental processes.

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[1] J. F. Meckel, *Handb. d. pathol. Anat.* I, p. 553.

On the other side, experimental teratology, which is doubtless a branch of pathology, has made most important advances in the knowledge of the laws of normal development, the laws which govern the details of the regular formation of the embryo. Here also no sharp line can be drawn between pathology and embryology. Pathology takes its place alongside of embryology, with equal right and equal importance.

Thus we see pathology placed centrally among the biologic sciences, bound inseparably to all of them, not subordinate to any but their equal, receiving help from all sides but giving as much in return. Lastly, it must be stated that it is the problem of life which forms the subject of pathologic work. Even though it wanders in its own ways, and possesses its especial questions, it is finally led to the general question of every biologic investigation.

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[1] Marchand, *Eulenburg's Real Encyclopaedie*, xv, 432, 1897; Bonnet, *Ergebn. d. Anat. u. Entwicklungsgesch.* IX, 820, 1899; Wilms, *Die Mischgeschwülste*, 1899–1902.

Points of contact with philosophy are always presented by these general biologic problems, and we need only name Lotze,[1] the physician and philosopher, and his work on *General Pathology as a Mechanical Science*, to find the close relationship between philosophy and pathology personified in modern times. Metaphysic consideration of empiric assertions is necessary, as Kant has taught, to draw general conclusions and formulate general rules and laws from the observation of nature. Biology, and not least, pathology, lead everywhere to the limits of our knowledge of nature, where fixed knowledge finds its end, where we must, with Du Bois Reymond,[2] acknowledge our ignorance of what lies beyond, but where philosophic contemplations point a higher and more general way out of our difficulty. These limits to our knowledge are not lasting, however, for pathology. We will not remain in ignorance as long as the knowledge of healthy and diseased life progresses, and the boundaries of natural science and philosophic contemplation of the problems are being extended. Increasing knowledge of facts must be the basis of philosophic contemplation, if this would have real value.

There was a time in pathology when philosophic conceptions outweighed all other considerations, and when it was believed that all the problems of general biology and those of general pathology could be solved by pure reasoning. This period of natural philosophy was as unfruitful for real progress in pathology as the period of dogmatism in the Middle Ages, when Aristotle and Galen were looked upon as the sum of all wisdom, and pathology was nothing more than philology, as all scientific work consisted principally in criticising and commenting upon the Greek writings.

This changed only after we emancipated ourselves more and more from the old dogmatic belief and through original investigations laid a true scientific foundation for pathology. The maxim of the great Morgagni,[3] "*Nulla autem est alia pro certo noscendi via, nisi quam plurimas et morborum et dissectionum historias, tum aliorum tum proprias collectas habere et inter se comparare*," as well as his other, "*Non numerandae sed perpendendae sunt observationes*," had to receive general recognition before pathology was enabled to take its place among the other natural sciences. This place it had lost, for in the renaissance of science in the sixteenth century pathology stood in close relation to the other natural sciences; and medicine was for centuries the bearer of all natural science and included all other sciences within itself, so that not only did the teachers of other sciences belong in many cases to the medical faculty, but zoölogy and botany, physics and chemistry, were taught by physicians. We need only recall Haller and his great teacher Boerhaave, who successively occupied the chairs of botany and chemistry, of practical and theoretic medicine, and attained fame in all these branches. All this has changed in the course of time; the children have separated from their mother and have further developed themselves, and their development to great sciences has proceeded more rapidly than that of pathology. The time is not long past when the emancipated looked down on pathology and would not recognize it as an equal science. Did not Virchow find it necessary, before the congress of German naturalists, in 1867,[1] to insist on the scientific equality of pathology, and to demand that the so-called exact natural sciences should recognize pathology as an equal companion.

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[1] Lotze, *Die allgemeine Pathologie und Therapie als mechanische Naturwissenschaft*, Leipzig, 1842.

[2] Du Bois Reymond, *Ueber die Grenzen des Naturerkennens*, Naturforscher-Versammlung in Leipzig, 1872.

[3] *De sedibus et causis morborum, per anatomen indagatis*, 1761.

In fact, as pathology (excepting in purely etiologic studies) cannot do without physics and chemistry, as she also strives to refer pathologic phenomena to physical and chemic laws, so she has given something to these sciences and even to the present time has furnished workers which have assured themselves a lasting place in the history of exact sciences. Is not the mention of the name of the physician, Robert Mayer, the discoverer of the law of conservation of energy, and of Helmholtz, who began his professorship in Königsberg with lectures on general pathology, sufficient proof? The literature of Röntgen, radium, and other light-rays shows sufficiently how to this day pathology takes part in the investigation of physical problems.

These investigations lead to another especially important field, that of chemistry. Questions which were determined in the chemical laboratory of my institute, the proof, namely, that by the effect of radium rays on cancer tissue impediments which stood in the way of the action of preëxisting cytolysins are set aside, are nothing but chemic questions. Thirteen years ago I stated in a rector's address,[2] that only pathologic chemistry on a basis of cellular pathology could take us further in the study of infectious diseases, that the chemistry of bacteria, the normal and pathologic chemistry of the cells, was the problem of the future. This statement can be enlarged upon; in whatever branch of modern pathology we seek progress, we finally always meet chemic questions, and it needs no prophet to tell us that the greatest progress of pathology in the immediate future will be along the lines of chemistry. In all directions pathologists have united with chemists to further the study of the chemistry of proteids. Physicians and pathologists have furthered the knowledge of precipitins, agglutinins, and lysins of various sorts, not only in their practical but also in their purely scientific relations, and have begun to study these substances along different lines.

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[1] *Ueber die neueren Fortschritte in der Pathologie,* Vortrag in der 2. allgemeinen Sitzung am 20. September, 1867.

[2] *Ueber d. Fortschritte der Aetiologie,* Göttingen, 4. June, 1891.

Pathology stands in close relation not only with that group of physical sciences which treat of life-processes and living organisms but also with the exact physical sciences. To these also many bridges lead, over which the connecting links flow in both directions, pathology giving as well as receiving. A separation of pathology from the other sciences could therefore only be made by force, for pathology forms an integral part of the science of life, biology. I do not consider it just, therefore, that in this Congress, bacteriology, which draws its greatest importance from that part which belongs to pathology, which is thus, principally, a part of pathology, has been placed by itself in Division C, "Physical Sciences" (*Naturwissenschaft*), and pathology in Division E, "Useful or Utilitarian Sciences." Is bacteriology not an eminently useful science? Has it not found the most widespread use in medical practice? Have not other branches of pathology, and especially pathologic anatomy, been reproached because it has done little for the prevention and treatment of disease, while bacteriology has done much in this direction? Yet bacteriology is put under physical sciences and pathologic anatomy with the rest of pathology among the utilitarian sciences! On what grounds can we consider human pathology as a different sort of science from the pathology of plants? If we class plant pathology with plant morphology and physiology as a part of biology (as is right), one must do the same for human pathology and place the biologic sciences in the closest relation with human anatomy and physiology. Human pathology is as much natural science and a separate branch of biology as is phytopathology, and pathology is no more a utilitarian science than normal anatomy and physiology. Is medical activity conceivable without anatomy and physiology? As little as without pathology! Has pathology only importance through its relation to practical medicine? Not at all. Pathologists also prosecute their scientific studies without regard as to whether their work will be of immediate practical value or not. They also follow the inner motive toward knowledge and truth. They wish to satisfy that desire for increased knowledge which is in every human breast, to share in disclosing the secrets of nature. If the acquisitions of pathology have had a greater and more immediate effect on medical treatment than those of anatomy and physiology, that does not alter its scientific quality in the least; that they were also useful has never injured other sciences or lessened their scientific value. No one will value chemic and physical sciences less because they have been the basis of the wonderful advance in technic and industry, as displayed to the wondering eyes in this exposition. Pathology rejoices in its relation to practical medicine and would neither miss nor lessen it, for as physics and chemistry constantly receive from practice stimulus to new endeavors and progress, so also pathology needs uninterrupted relation to medical art. But it remains first of all an independent physical science, which in its three branches, pathologic anatomy, physiology, and chemistry, stands on an equal plane with normal anatomy and physiology and physiologic chemistry, with them and etiology forming the scientific basis for practical medicine.

But as for ages past a certain socialistic or rather humanitarian spirit has ruled in medicine (and to medicine pathology must always belong), which effected that with all pride over scientific demonstrations the real and true joy over scientific progress was not reached, if not only wisdom and knowledge were furthered, but also something of value has been accomplished for the general good, so it may also remain in the future. Pathology will be recognized as a natural science, but it will be its pride and joy also in the future to be and to remain a utilitarian science.

THE BEHAVIOR OF NATIVE JAPANESE CATTLE IN REGARD TO TUBERCULOSIS (PERLSUCHT)

BY SHIBASABURO KITASATO

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In Japan it is a fact of common knowledge that the native Japanese cattle are free from tuberculosis (perlsucht) under ordinary conditions, while imported and mixed types of cattle (that is, such as descend from foreign cattle on the father's side, from native cattle on the mother's) contract the disease. This fact would be a very noteworthy one if we could suppose that our native animals are naturally insusceptible to tuberculosis, and are not so simply because they have not had the opportunity to become infected. As far as I know, no race of cattle is known to us which can prove ownership to a real natural immunity against tuberculosis. The claim has been made often enough, but each time the falsity of the claim could be demonstrated through inoculation experiments. To determine the position of the native Japanese cattle in regard to tuberculolsis the following experiments were performed.

Before relating these experiments, however, I would like to make a few general remarks concerning tuberculosis of the human race in Japan.

Table I.—Mortality From Tuberculosis in Japan Between the Years 1892 and 1901.

Year.	Population.	Total number of deaths.	Pulmonary Tuberculosis.	Other respiratory diseases.
1892	41,044,739	894,875	57,292	109,705
1893	41,399,874	930,009	57,798	133,162
1894	41,788,335	845,293	52,888	98,963
1895	42,210,179	854,392	58,992	96,531
1896	42,623,931	904,473	62,790	105,697
1897	43,064,658	875,103	65,597	101,360
1898	43,540,768	891,339	72,708	113,365
1899	43,960,008	920,340	75,226	108,262
1900	44,457,973	910,517	78,972	120,761
1901	44,968,769	932,365	81,669	123,929

Year	The relation of the total mortality and mortality from tuberculosis to the total population (compared with 1000 inhabitants).			Percentage of tuberculosis mortality to the total mortality.	
	Total mortality.	Pulmonary tuberculosis.	Other respiratory diseases.	Pulmonary tuberculosis.	Other respiratory diseases.
1892 ...	21.80	1.40	2.67	5.40	12.26
1893 ...	22.46	1.40	2.73	6.21	12.17
1894 ...	20.23	1.27	2.37	6.26	11.71
1895 ...	20.24	1.40	2.29	6.90	11.30
1896 ...	21.22	1.47	2.48	6.94	11.70
1897 ...	20.32	1.52	2.35	7.50	11.58
1898 ...	20.47	1.76	2.37	8.16	12.72
1899 ...	20.94	1.71	2.46	8.17	11.76
1900 ...	20.48	1.78	2.72	8.67	13.26
1901 ...	20.73	1.79	2.76	8.76	13.29
Average	20.88	1.55	2.54	7.41	12.19

Mortality from tuberculosis in the eight largest cities, all of them having more than 100,000 inhabitants, and in the other towns of Japan during the years 1899 and 1900:

TABLE II.

Place and Year.	Number of inhabitants.	Total mortality.	Pulmonary tuberculosis.	Tuberculous meningitis.	Intestinal tuberculosis.	Tuberculosis other organs.	Total tuberculosis.	Other respiratory diseases.
Tokio . 1899	1,468,953	29,274	4,238	343	499	37	5,117	2,812
1900	1,497,675	27,869	4,254	336	458	56	5,104	3,767
Kioto . 1899	356,956	7,905	1,132	99	168	14	1,413	918
1900	364,673	7,703	1,204	159	176	25	1,564	803
Osaka . 1899	835,203	16,407	2,257	175	316	9	2,757	2,002
1900	865,021	15,991	2,431	221	337	17	3,006	2,036
Yokohama . 1899	195,364	2,829	278	40	44	00	362	353
1900	201,036	2,487	401	32	34	3	470	305
Kobe . 1899	225,970	5,360	711	36	88	1	836	590
1900	240,917	4,808	719	27	74	5	825	642
Nagasaki . 1899	114,144	1,489	196	12	15	1	224	192
1900	125,231	1,804	234	22	34	4	295	189
Nagoya 1899	243,767	4,622	543	29	84	3	659	591
1900	252,068	4,675	597	19	65	1	682	627
Hiroshima . 1899	126,039	1,937	207	3	24	4	238	305
1900	133,732	2,179	256	16	20	2	294	289

TOTAL OF THE EIGHT CITIES.

1899......	3,566,394	69,823	9,562	737	1,238	69	11,606	7,663
1900......	3,680,351	67,516	10,097	832	1,198	113	12,240	8,658

ALL OTHER PLACES.

1899......	40,393,614	862,264	46,376	2,014	7,178	435	56,003	105,792
1900......	40,777,622	843,228	49,428	2,344	7,228	531	59,531	116,613

SUM TOTAL OF ENTIRE JAPAN.

1899......	43,960,008	932,087	55,938	2,751	8,416	494	67,609	113,455
1900......	44,457,973	910,744	59,525	3,176	8,426	644	71,771	125,271

THE RELATION OF THE TOTAL MORTALITY AND MORTALITY FROM TUBERCULOSIS TO THE NUMBER OF INHABITANTS (CALCULATED TO 1000 INHABITANTS).

Place	Total mortality.	Pulmonary tuberculosis.	Total tuberculosis.	Other respiratory diseases.
Tokio	19.23	2.86	3.45	2.22
Kioto	21.63	3.24	4.13	2.38
Osaka	19.06	2.76	3.39	2.37
Yokohama	13.41	1.71	2.10	1.41
Kobe..............	21.78	3.06	3.56	2.64
Nagasaki	13.76	1.80	2.17	1.59
Nagoya..............	18.75	2.30	2.70	2.46
Hiroshima	15.64	1.78	2.05	2.29
Average of 8 cities ...	18.95	2.71	3.29	2.25
Other towns	21.01	1.18	1.42	2.74
Average figure.......	20.84	1.31	1.58	2.71

THE PERCENTAGE OF THE TUBERCULOSIS MORTALITY TO THE TOTAL MORTALITY

Place	Pulmonary tuberculosis.	Total tuberculosis.	Other respiratory diseases.
Tokio	14.86	17.89	11.51
Kioto	14.97	19.07	11.03
Osaka	14.47	17.79	12.46
Yokohama	12.77	15.65	10.50
Kobe	14.06	16.34	12.12
Nagasaki	13.09	15.76	11.57
Nagoya	12.26	14.42	13.10
Hiroshima.........	11.25	12.93	14.43
Average of 8 cities .	14.31	17.36	11.88
Other towns	5.62	6.77	13.04
Average figure	6.27	7.56	12.95

A valuable paper on the statistics of tuberculosis has been written by Tamaye Ogiya, under the directorship of Professor Sata, from the pathologic institute at Osaka. This authoress states that during a period of three and a half years she has found among 250

TABLE III.

Place and year.		Population.	Total number of deaths.	Deaths from tuberculosis.	Total number of cattle.	Number of diseased cattle.	Perlsucht.
1896	M	43,815	807	23 (2.85%)	5,188	36	......
	O	......	......	......	......	......	......
1897	M	44,029	768	18 (2.34%)	5,585	16	......
	O	......	......	......	......	......	......
1898	M	43,357	936	32 (3.41%)	5,389	21	......
	O	35,026	697	60 (8.60%)	1,964	37	......
1899	M	43,370	805	31 (3.85%)	5,870	25	......
	O	35,104	704	80 (11.30%)	1,952	115	......
1900	M	43,821	778	33 (4.24%)	5.491	20	......
	O	35,346	673	51 (7.55%)	2,257	75	......
1901	M	44,093	701	48 (6.85%)	5,473	32	......
	O	35,526	642	39 (6.07%)	2,214	67	......
1902	M	45,043	762	58 (7.61%)	5,109	37	......
	O	35,607	684	42 (6.14%)	2,245	31	......
1903	M	......	766	62 (8.09%)	5,352	25	......
	O	......	678	88 (13.00%)	....	46	......

M., Mikato; O., Osaka.

TABLE IV. — SIMILAR TABLE FROM THE DISTRICT ABU IN YAMA-GUCHI-KEN FOR THE YEARS 1901 TO 1903.

Town-ship.	Year.	Population.	Total mortality.	Mortality from tuberculosis.	Total number of cattle.			Number of diseased cattle.			Perlsucht.
					Native.	Mixed race.	Imported.	Native.	Mixed race.	Imported.	
Sammi	1901	3,246	51	1 (1.96%)	426	....	...	2	...	...	....
	1902	3,333	48	7 (14.58%)	436	....	...	1	...	...	....
	1903	3,262	73	3 (4.10%)	418	....	...	...	...	...	....
Udago	1901	2,022	33	1 (3.00%)	202	....	...	1	...	...	....
	1902	2,058	29	1 (3.44%)	203	....	...	...	...	...	....
	1903	2,015	43	....	203	....	...	...	...	...	....
Fukuga	1901	2,839	79	....	581	....	...	3	...	...	....
	1902	2,892	47	2 (4.25%)	511	....	...	3	...	...	....
	1903	2,901	71	2 (2.81%)	521	....	...	3	...	...	....
Susa ...	1901	5,223	98	5 (5.10%)	418	....	...	2	...	...	....
	1902	5,225	91	4 (4.40%)	414	....	...	3	...	...	....
	1903	5,292	106	4 (3.77%)	404	....	...	3	...	...	....
Akiraki	1901	2,924	49	3 (6.10%)	278	....	...	...	...	...	....
	1902	2,547	40	1 (2.50%)	257	1	1	3	...	...	....
	1903	2,603	39	1 (2.56%)	268	12	...	2	...	...	....
Nako	1901	3,957	78	4 (5.12%)	262	....	...	1	...	...	....
	1902	3,932	79	4 (5.06%)	262	....	...	...	...	...	....
	1903	4,058	54	1 (1.85%)	257	....	...	...	...	...	....
Ogawa	1901	4,180	106	9 (8.49%)	825	....	1	2	...	...	....
	1902	4,205	87	2 (2.30%)	734	9	2	1	...	...	....
	1903	4,247	86	6 (6.97%)	593	25	2	...	...	...	....
Tama-saki	1901	3,952	89	5 (5.61%)	309	....	...	2	...	...	....
	1902	3,994	83	4 (4.81%)	267	....	...	...	...	...	....
	1903	3,851	95	4 (4.21 %)	257	....	...	2	...	...	....

autopsies 116 cases of tuberculosis, amounting to 46.4% of the total. Of the tuberculosis patients, 20 (17.3%) were under 18 years, 96 (82.2%) were more than 18 years; among these patients she found 90 (77.6%) who presented lesions showing primary pulmonary tuberculosis, 12 (10.34%) who had primary intestinal tuberculosis. Among the latter 6 were more and 6 less than 18 years. Basing the statement upon this paper, it may be said that the occurrence of primary intestinal tuberculosis is not rare in Japan either among adults or children, although cow's milk is employed but little by us for the nourishment of children.

The table on the preceding page refers to districts in which man suffered from tuberculosis, but his cattle were free from it (the years considered are from 1896 and 1903); they are the districts Mikata and Osaka at Tasima in Hiyogo-Ken; these districts possess only native cattle.

The following table shows the number of cases of tuberculosis (perlsucht) among the slaughtered cattle found during the years 1901 to 1903 in five large cities :

TABLE V.

Place.	Native cattle.		Mixed races.		Imported.	
	Number of slaughtered head.	Perlsucht.	Number of slaughtered cattle.	Perlsucht.	Number of slaughtered cattle.	Perlsucht.
Tokio	72,780	40	5,299	2,293 (43.27%)	4	2 (50%)
Tokio	....	..	4,416 (calves)	7 (0.16%)	..	....
Kioto	17,643	..	1,139	566 (49.69%)	9	9 (100%)
Osaka	50,173	..	2,808	641 (22.89%)	41	13 (31.7%)
Yokohama ..	30,275	24	4,021	555 (13.85%)	..	....
Kobe	38,135	..	501	159 (31.73%)	..	....
Kobe	......	..	1,700 (calves)	....	..	....

It must be remembered that for a long time neither Tokio nor Yokohama have possessed any purely native cattle; it is highly probable that the tuberculosis animals mentioned in the foregoing table as native animals belonged in reality to mixed races, inasmuch as we have mixed races which resemble the native animals so closely that even an experienced veterinary physician cannot distinguish between them.

The examination of bovines (inclusive of the mixed races and the imported cattle) for tuberculosis (perlsucht) which has been carried on in Japan since last September and up to March of this year through tuberculin injections and other methods of examination, has given the following results:

TABLE VI.

Calculations are made on a basis of 1000 bovines; among them were found the following number of tuberculous:

Tokio-Fu	377.54	Yamagata-Ken	47.45
Kioto-Fu	133.44	Akita-Ken	36.72
Osaka-Fu	57.66	Fukui-Ken	273.98
Kanagawa-Ken	147.89	Ishikawa-Ken	20.19
Hiyogo-Ken	220.79	Toyama-Ken	91.93
Nagasaki-Ken	45.72	Toritori-Ken	14.49
Niigata-Ken	26.13	Shimane-Ken	2.94
Saitama-Ken	332.83	Okayama-Ken	11.43
Gumma-Ken	298.64	Hiroshima-Ken	36.27
Chiba-Ken	26.18	Yamaguchi-Ken	41.63
Ibaraki-Ken	162.72	Wakayama-Ken	79.79
Tochigi-Ken	187.50	Tokushima-Ken	39.89
Nara-Ken	209.37	Kagawa-Ken	1.47
Miye-Ken	114.30	Yehime-Ken	10.48
Aichi-Ken	333.47	Koochi-Ken	5.30
Shidzuoka-Ken	14.00	Fukuoka-Ken	188.05
Yamanashi-Ken	199.77	Oita-Ken	20.53
Shiga-Ken	169.83	Saga-Ken	75.74
Gifu-Ken	64.62	Kumamoto-Ken	60.06
Nagano-Ken	93.08	Miyasaki-Ken	55.21
Miyagi-Ken	97.20	Kagoshima-Ken	24.96
Fukushima-Ken	40.89	Hokkaido-Ken	87.30
Iwate-Ken	6.78		
Aomori-Ken	7.15	Average of all	56.71

The following table shows how little cow's milk is partaken of in Japan:

TABLE VII.

For every 10,000 inhabitants there are milk-cows in

Tokio-Fu	17.50	Akita-Ken	2.64
Kioto-Fu	15.78	Fukui-Ken	4.90
Osaka-Fu	8.21	Ishikawa-Ken	5.05
Kanagawa-Ken	11.81	Toyama-Ken	1.98
Hiyogo-Ken	5.60	Toritori-Ken	1.35
Nagasaki-Ken	5.88	Shimane-Ken	2.96
Niigata-Ken	3.91	Okayama-Ken	3.12
Saitama-Ken	2.82	Hiroshima-Ken	3.05
Gumma-Ken	7.68	Yamaguchi-Ken	5.63
Chiba-Ken	18.50	Wakayama-Ken	4.75
Ibaraki-Ken	1.75	Tokushima-Ken	1.70
Tochigi-Ken	2.70	Kagawa-Ken	2.52
Nara-Ken	2.86	Yehime-Ken	1.42
Miye-Ken	6.49	Koochi-Ken	2.00
Aichi-Ken	5.08	Fukuoka-Ken	3.31
Shidzuoka-Ken	9.46	Oita-Ken	1.36
Yamanashi-Ken	2.86	Saga-Ken	3.33
Shiga-Ken	5.08	Kumamoto-Ken	2.37
Gifu-Ken	6.37	Miyasaki-Ken	1.84
Nagano-Ken	9.35	Kagoshima-Ken	2.28
Miyagi-Ken	3.78	Okinawa-Ken	1.84
Fukushima-Ken	1.33	Hokkaido-Ken	10.16
Iwate-Ken	1.61		
Aomori-Ken	2.05	Average of all	5.65
Yamagata-Ken	4.87		

One milk-cow furnishes with us in the course of a year a daily average of five liters of milk. From this follows that in Tokio-Fu each individual consumes daily 8.85 cm., and in entire Japan 2.825 cm. of milk.

I. *Experiments concerning the Susceptibility of Native Bovines to Imported Perlsucht*

Experiment A. On January 22, 1904, we treated altogether 15 native calves of pure race (from three to six months old and having a body-weight of from 60 to 90 kilograms), which came from a region where, until now, no foreign cattle had ever been imported, in the following manner:

Each of seven animals was inoculated with 1 cm. of an emulsion containing a pure culture of highly virulent perlsucht bacilli; in two of the animals the injections were made into the cervical vein, in two into the abdominal cavity, in two into the trachea, and one was injected subcutaneously. Each of three calves was permitted to inhale 0.5 gm. of living but dried-up bacilli. The remaining five were each infected with 1 cm. of an emulsion from tuberculous organs, all of which contained very large numbers of tubercle bacilli; in one the intravenous route, in two the intraperitoneal, in one the intratracheal, and in one the subcutaneous route was chosen.

As control animals were employed five animals of mixed races. One of these received an injection of the emulsion of the tuberculous organs into the cervical vein, three into the abdominal cavity, and one was permitted to inhale a dried-up pure culture.

Before beginning the experiments, each of the calves was injected with 0.3 cm. tuberculin, to determine the existence of previous tuberculosis, but all were found free of the disease.

Three animals died 24 to 72 days after the experiment; the remaining 12 were killed after periods varying from 225 to 363 days.

One calf, which had been given an intraperitoneal injection of an emulsion of the pure culture of perlsucht bacilli, died as soon as the twenty-fourth day. At the autopsy it was found that the intraperitoneal lymphatic glands were swollen, and that the outer lower part of the left kidney contained yellowish nodules. The lungs were markedly hyperemic and contained but little air, but tubercles could not be demonstrated in any part of them. In the renal nodules the microscope revealed a small number of tubercle bacilli, which, when inoculated into the subcutaneous tissues of a guinea-pig, produced typical symptoms and signs of tuberculosis.

A second animal, which had been injected intravenously with the emulsion from tuberculous organs, was found dead on the fortieth day. The lungs contained very large numbers of tuberculous nodules and the glands of the thoracic cavity were swollen to an enormous size.

The third animal, which had received an injection into the trachea with the tuberculous emulsion, died after 72 days. The post-mortem examination revealed both thyroid glands hyperemic and swollen; at the point of injection the trachea was the seat of a mass the size of a pigeon's egg; the surface of this mass was covered with countless miliary tubercles. The lungs contained similar miliary nodules, and the right lung was even adherent to the pleura. The mesenteric glands were normal.

The remaining 12 calves were killed; three of them were more or less tuberculous. The one which had inhaled 0.5 gm. pulverized tubercle bacilli was killed after 259 days; the tuberculin reaction before its death gave a doubtful result. The autopsy showed the presence of a few very small nodules in the laryngeal mucous membrane and of one nodule in the anterior wall of the left cardiac chamber; this last one contained very many tubercle bacilli.

The second animal had been injected with 1 cm. of the emulsion from the tuberculous organs; it was killed after 256 days. The tuberculin reaction was positive before its death. The post-mortem examination showed the inguinal glands in the neighborhood of the point of injection very much swollen; the liver contained a few nodules; all the intraperitoneal glands were swollen, and some of them were already the seat of cheesy degeneration. The lungs were normal.

The third heifer had received an injection of 1 cm. of the emulsion from a tuberculous lung into its abdominal cavity; it was killed after 280 days. The tuberculin reaction before its death had also been positive. The section revealed the peritoneum and liver to be the seat of a small number of tubercles varying in size from a pea to a small bean; some of them were cheesy. Both lungs were studded with numerous grayish-white, hard miliary nodes.

The other nine animals were found to be entirely free from tuberculosis.

The five control animals were killed after from 217 to 364 days. The autopsy showed four of them to be suffering from tuberculosis and one to be free from it.

If the above-mentioned results are considered collectively it will be seen that from among 15 experimental animals six became tuberculous, while nine were demonstrated to be insusceptible. It is further worthy of note that the changes in the infected organs were relatively very slight.

From a review of the entire experiment it can be seen that the native Japanese bovines are to some extent susceptible to perlsucht experimentally, but only if doses of tubercle bacilli are inoculated so large as never to be received in the course of a natural infection.

We can conclude from this that our native cattle show so little susceptibility to perlsucht that natural infection appears almost impossible.

Experiment B. The same experiment was repeated on May 27 of this year; this time 33 native calves from 3 to 8 months old, and weighing from 40 kilograms to 90 kilograms were employed. The method of the experiment was exactly the same as in Experiment A. To obviate too frequent repetitions these experiments will be reported only briefly.

Fifteen of the animals were infected intravenously; in 10 pure cultures of perlsucht bacilli were employed, and in 5 the emulsion from tuberculous organs; 8 were infected intraperitoneally (5 with pure cultures and 3 with emulsion from organs); 3 were treated with inhalations of pure cultures, while the last seven were infected subcutaneously (5 with pure cultures, 2 with organ emulsions).

Four mixed race animals were employed as control; in two of them the injections were made intravenously (one with pure cultures and one with organ emulsion); in the other two intraperitoneal injections were given (one with pure culture and one with organ emulsion).

Before the experiment all of the animals were injected with tuberculin; in none of them was a positive reaction obtained.

Of the 33 animals, 7 perished in from five to 63 days after the inoculation with the perlsucht bacilli, from a number of different causes. Five of these animals showed some traces of the disease; the other two were entirely free from it.

The remainder of the 33 calves are still alive (August 10, 1904), and apparently in the best of health.

II. *Experiments concerning the Susceptibility of Native Bovines and of the Mixed Races to Human Tuberculosis*

The experiments were performed on 14 calves, of which 6 were Japanese, and 8 belonged to the mixed types. Eight of them were treated with pure cultures; 2 of them were given intravenous, 3 intraperitoneal, and 1 intratracheal injections; 2 were given inhalations; the other 6 were treated with an emulsion made of the organs of a man, whose death was due to miliary tuberculosis; the organs contained numerous fresh tubercle bacilli; 3 were infected intravenously, and 3 intraperitoneally.

The tuberculin reaction before the experiment was negative in all the instances.

Two of the native animals, having had pure cultures injected into the cervical vein, died after 30 days and 56 days. One of them developed high fever eight days after the injection, this persisting for some time; the animal died on the thirtieth day, with symptoms of general debility. The autopsy showed the apices of both lungs dark red, and moderate swelling of some of the glands of the thoracic cavity. The mucous membranes of the pharynx and larynx were inflamed; the neighborhood of the vocal cord was covered with mucus in which a small number of tubercle bacilli could be demonstrated.

The second animal developed considerable fever about the tenth day, which also lasted for a long time. After 40 days, conjunctivitis appeared in both eyes, this gradually becoming so violent as to destroy vision entirely; death resulted on the fifty-sixth day after the injection, and as in the case of the first animal, seemed to be due to weakness. The organs of the thorax and abdomen were found normal, excepting that the left lung contained a very small pea-sized tubercle, in which a few tubercle bacilli were demonstrable. None of the other organs contained anything abnormal.

In neither of these cases are we permitted to speak of infection, as in the first place, the duration of illness was too short, and in the second place, the tuberculous lesions so slight that they could be found only with difficulty, and it goes without saying that in the short time having elapsed between injection and death the tubercle bacilli introduced into the organism could still have been alive.

The rest of the calves, 12 in number, were killed after from 101 days to 327 days, but in no instance could a trace of tuberculosis be found.

The number of calves and heifers used for these experiments was altogether 71; of these 52 were purely native animals and 19 had descended from mixed races.

The tubercle bacilli from the pure cultures as well as from the tuberculous organs before being utilized for the experiments, had been inoculated into guinea-pigs to note whether or not their virulence was great enough. All of the guinea-pigs perished after the usual lapse of time of typical tuberculosis.

From the results mentioned, the following conclusions can be drawn :

(1) Human tuberculosis is as frequent in Japan as in the civilized countries of Europe and America.

(2) Primary intestinal tuberculosis is relatively common in adults and children, although cow's milk plays no rôle at all in the feeding of children.

(3) There are large districts in Japan, where, in spite of the existence of human tuberculosis, the cattle remain absolutely free from the disease. In these regions it is not customary to consume either meat or milk from bovines.

(4) This is very important proof for the fact that under ordinary conditions human tuberculosis is not infectious for bovines, as the opportunities for infection certainly cannot be lacking.

(5) Among Japanese in general very little cow's milk is used and especially is it employed but little for the dietary of children.

(6) Under natural conditions the native animals show but very little susceptibility for perlsucht. If large doses of perlsucht bacilli are inoculated into them either intravenously or intraperitoneally, they become tuberculous to a certain degree; they do not seem to be at all susceptible to subcutaneous infection.

(7) The imported and mixed race animals are very susceptible to perlsucht.

(8) Human tuberculosis is not infectious for native and mixed race animals.

Before concluding I would like to say a few words concerning the two opposing opinions of Koch and von Behring. As is well known, Koch, at the congress in July, 1901, at London, made the statement that human tuberculosis is absolutely different from bovine tuberculosis, a conclusion which he had come to after two years of experimentation on young heifers. Von Behring took issue with this statement at the Congress of Natural Scientists, at Kassel, in September of last year. Von Behring believes that the milk taken by nurslings (cow's milk) is the chief source for the development of tuberculosis. He also stated that human tuberculosis is identical with that of bovines.

The fact has already been mentioned that primary intestinal tuberculosis is quite frequent in Japan, even though the natives drink but very little cow's milk, and even though they employ it but very little for the nourishing of their children; if the mother's milk does not suffice, a wet nurse is instantly taken into the house. This clearly proves that human tuberculosis in Japan can only be transmitted from man to man. And from the fact that native Japanese cattle are free from tuberculosis, and also are so little susceptible to it as to make it almost impossible for natural infection to take place, we can conclude that bovine tuberculosis was imported into Japan only after the introduction of foreign cattle. These importations, however, began only about 30 years ago, while human tuberculosis has existed in Japan as long as we have chronicles. Of especial deciding importance for the statement that human tuberculosis is different from that of bovines is the following: If this were not the case, it would be impossible to find districts in which bovines are entirely free from tuberculosis, in spite of their close connection with tuberculous human beings, and who are constantly giving the domestic animals the opportunity to infect themselves.

On account of these reasons it is impossible to trace the tuberculous infection of man back to cow's milk respecting bovine tuberculosis, and therefore I must subscribe to the opinion of Koch and say that the danger of the conveyance of tuberculosis from man to man occupies first place. Concerning the views of von Behring in relation to the mode of infection, I must confess that by us in Japan the milk fed to nursing infants (cow's milk) cannot play a rôle in the contraction of tuberculosis.

SHORT PAPERS

Dr. Carlos T. Finlay, Sanitary Chief of the Cuban Government, presented an interesting paper to this Section on "The Leucocytes," with suggestions as to the rôle that may be assigned to them in connection with cell nutrition and immunization.

Dr. George Coromilas, of Athens, Greece, presented a paper to this Section upon the healing properties of sulfite of carbon, particularly in chronic maladies of the lungs, and the treatment of tuberculosis.

Professor Tessier, of the University of Lyons, France, presented a paper to this Section on "Some New Studies of the Pathology, Diagnosis, and Special Complications of the Abdominal Aorta."

SECTION D

THERAPEUTICS AND PHARMACOLOGY

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(*Hall* 13, *September* 24, 3 *p. m.*)

CHAIRMAN: DR. HOBART A. HARE, Jefferson Medical College.
SPEAKERS: PROFESSOR OSCAR LIEBREICH, University of Berlin.
SIR LAUDER BRUNTON, F. R. S., London; D.C.L. Oxon.
SECRETARY: DR. H. B. FAVILL, Chicago, Ill.

THE RELATION OF THERAPEUTICS TO OTHER SCIENCES IN THE NINETEENTH CENTURY

BY OSCAR LIEBREICH

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EVERY political historian will prefer to trace the development of a period of history from one distinct event. A chronological introduction cannot be of such importance to him as an historical survey, in which events of great moment form the basis of a new development.

What is true of political evolution applies also to the growth of every branch of natural science and medicine. The first year of a century, though filling men with joyful confidence and new hopes, has not the same attraction for the investigator; and yet, in order to obtain a general view of the growth of the different branches, it is desirable not to lose sight of this idea, but to consider all the stages of progress in common from a certain point of time, and thus the study of the history of therapeutics must also be subordinated to this aim.

Although the evolution of the nineteenth century has frequently been threatened by heavy political clouds, we have seen them often pierced by the sun of progressive science, which, especially in that century, has called forth a fertility of culture such as has scarcely been witnessed in any previous period of one hundred years. The past century more than any other has been distinguished by the multitude of newly discovered facts in natural science, as well as by the perfection and extension of the ideas of great discoverers of the previous century.

It is the age in which the greatest progress in natural science has been made. The vast numbers of new discoveries in medicine have lessened, or even almost suppressed, on the part of many persons, the feelings of admiration for each new acquisition.

The new phenomena and experiences which confront us on all sides surpass the wildest dreams described in former centuries as the eccentricities of fanciful minds. The abundance of material compels our admiration and allows the astonished eye no time to gaze long at one occurrence, for new impressions already crowd it out.

The nineteenth century has spoiled us; our demands for new acquisitions increase, and we grow impatient to know more. In this unsettled state the laborious work of the individual often seems lost, but the true scholar is buoyed up by the gratifying knowledge that mighty buildings can only be constructed of a mosaic made up of single stones. Yet, truly, humanity often settles down in a new building without admiring either the work of the architect or his material.

Moreover, the capability of enjoying nature and whatever we have added to our knowledge of the universe by laborious experiments does not appear to be a natural gift of man. Only education and culture can awaken the enjoyment of what is and of what is about to be. Mighty natural phenomena, indeed, fill the casual onlooker with admiration, but the observation of what is harmonious in nature, and the capacity of assimilating it for our own culture, can be gained only through education. This also holds good of art, and it is even more difficult in science. Since the uneducated majority is often inclined to pass by the greatest events with indifference, the nineteenth century has spared no pains to inform humanity of all the great innovations, to educate them, and thus to gain friends for the progress of civilization. This, indeed, is the object of your Congress.

There are various ways in which therapeutics (and it is here chiefly a question of pharmacodynamic therapeutics, that is such as concerns itself not with mechanical means but with chemical-physical processes) may develop.

New knowledge of the conditions of life of the organism often lead to remarkable discoveries in therapeutics. Thus physiology, especially the functions of the different organs, is of the highest importance for the progress of therapeutics.

A striking example of this is furnished by digitalis. Originally this plant was simply a popular remedy, which, like many substances in use among the people, proved efficacious in the case of many diseases, while, of course, of no avail in others.

When William Withering, in 1785, undertook a careful examination of digitalis, it was used for phthisis, dropsy, and scrofula, it is true, and its power of slowing the pulse was known, but was not utilized therapeutically. A proof of how little significance was attached to these purely clinical experiments may be found in the changes as to the admission of digitalis to the London Pharmacopeia. In the year 1721 it was included; in 1746 rejected, and not reaccepted until 1778.

Now in the year 1846, Weber made the surprising discovery that the vagus nerve has an inhibitory influence upon the heart, *i. e.*, that exciting this nerve causes slower pulsation, and that cutting it occasions extreme acceleration of the action of the heart. This decisive experiment formed the basis of Traube's clinical investigations, and he was able to prove that the effect of digitalis on the heart corresponded to the excitation or section of the vagus nerve. This fact has been utilized clinically in diseases of the heart, arteriosclerosis, and dropsy,— and now upon a firm basis,— so that digitalis has emerged from its former position of uncertainty and taken a place among the efficient and reliable remedies, and we can safely say that it will not again disappear from the pharmacopeia, at any rate not owing to any uncertainty as to its effect.

Such investigations have now been undertaken with a number of other preparations, and on a large scale, such as, for instance, the clinical researches of Sir Lauder Brunton on "casca" (erythrophleum) and of Sir J. T. Fraser on Strophanthus hispidus, a plant similar to digitalis, but differing in its effect on the vaso-motor system, and which was also soon adopted in therapeutics. Much the same may be said of atropine, which chiefly through the knowledge of its physiological effect on the iris, on the non-striated muscular system and the glandular secretions, affords us an exact indication of its scope of utility in disease.

Thus we have here a source of fresh observations. Often the functions of the organism are affected in an isolated manner that we should scarcely have thought possible, for instance, by yohimbin. This physiological method is applicable to all chemical bodies, and the progress in our knowledge of curative powers depends solely on the progress of experimental physiology.

The physiological action, however, does not always remain within the limits of what is normal, for it may sometimes become pathological. This was remarked by various scientists as early as the middle of the eighteenth century, and shortly before the beginning of the nineteenth century (1799) A. Fr. Hecker expressed this view in his *Physiologia Pathologica*, *i. e.*, in "the theory of the composition and functions of the human body and its different parts in an abnormal condition."

How differently we may view physiologically active bodies can best be seen in the blood. But here, too, we observe that a rational system of therapeutics only became possible in the nineteenth century after a knowledge of the physiological effects had been gained. Berzelius was the first to recognize the presence of iron in the blood. The discovery of a ferruginous coloring-matter of the blood, hemoglobin, did not follow until much later. It is true that in 1854 Wöhler declared globulin and hematin to be contained in the blood corpuscles. But Funke (1852) and Lehmann (1853) had already established the fact that the coloring-matter of the blood, hemoglobin, is a distinct crystallizable substance which is capable of absorbing and giving off oxygen. Hemoglobin, we may say, is, to a certain extent, the quintessence of the respiratory activity. This function may be destroyed by inhaling carbonic oxide which enters into so close a combination with the coloring-matter of the blood that its respiratory function ceases. Thus blood in such a state is a menace to life which cannot be obviated by any drug, but we are able since the respiratory function of the blood has been understood to avert this danger in most cases by removing the poisoned blood and transfusing fresh blood.

The greatest hopes for the further development of therapeutics are raised by the fact that chemical substances are capable of restoring pathologico-physiological processes to a normal state. Here we may cite the antipyretics, which are able in the most striking manner to reduce to the normal state a rise of temperature, that is, a febrile phenomenon.

The drugs just mentioned are therefore of great importance in therapeutics as symptomatic remedies. Of course, they are in no way able to destroy the cause of disease, but merely alleviate or avert injurious symptoms. For the physician, however, this very quality is of paramount importance in the majority of cases. The cause of disease may disappear through the spontaneous healing process of the organism, while the symptoms are removed, which, had they been left alone, would inevitably have led to the death of the patient. Yes, we may say that it is one of the greatest aims of therapeutics to treat disease symptomatically, for we must endeavor to ease the sufferings of humanity, and the great advantage of this method of healing becomes specially evident when the cause of sickness cannot be destroyed by any remedy hitherto known. This may best be demonstrated in the treatment of poisoning. If, for instance, through a mistake, or for any other reason, a deadly dose of strychnine enter the system, the sufferer will expire under the symptoms of suffocation, caused by the convulsive contraction of the respiratory muscles. As, however, we are enabled to arrest this spasmodic contraction by means of chloroform, chloral hydrate, and other drugs, we can thus give the system time to eliminate the strychnine causing the illness. This being entirely thrown off, the morbid phenomena also disappear, and complete recovery soon ensues. It is possible, though as yet unknown, that purely symptomatic remedies may also influence the cause of disease.

At the beginning of the nineteenth century, chemistry was still of little service to the science of medicine. True, Lavoisier's greatest discovery in regard to metabolism in the organism was known, that is, that the oxygen of the air causes combustion, and when inhaled accomplishes the same object in the system. This must have given medical men an entirely new perception of the processes of life, but the time had not yet arrived for experimental work on this subject.

Even at that time numerous elements were known, 30 in number, whereas at the end of the century 76 elements had been found. A number of these elements were made use of in therapeutics in a pure state or in combination, without our being able to base their application upon rational, theoretical hypotheses, as, for instance, in the case of iron and its compounds, the use of which extends to the remotest times. On the other hand, there were among them elements employed as drugs, such as antimony, which first came into use in the Middle Ages, and which may be cited less as a proof of the therapeutic value of this matalloid than of the antiquated prejudice of a French faculty which absolutely refused to acknowledge any "drug," owing to its predilection for blood-letting. The rage of dogmatic physicians may be recognized in the words of the anathema against Torpet (cf. O. Liebreich, *Die historische Entwicklung der Heilmittellehre*, Lecture, Berlin, 1887).

On the other hand, the science of therapeutics placed great hopes in the isolation of alkaloids, which marked the beginning of the century. This era began with the recognition of the importance of morphia by Sertürner in the year 1804. Then followed the discovery of nicotine by Vauquelin in 1809, quinine in 1811, cinchonine in 1820, and of strychnine in 1818. This, at any rate, suggested the method of obtaining from extracts, frequently incumbered by useless matters, the active principle, and making it available for therapeutics, and hence a certain practical utility must even nowadays be accorded to pharmaceutical chemistry.

As regards a knowledge of the mode of action, however, the problem not only lies in the chemical composition and recognition of the substance employed, but also in the chemism of the organism. Outside the organism it is a lifeless substance, but in the system it is not only the substance itself but its metabolism and manner of action which must be taken into consideration. The theory of metabolism can only be of decisive value for therapeutics when not only the properties of the drug applied but also the chemical action of the organism are so far known as to enable us to judge of their mutual effect. For this reason, of course, a knowledge of the chemistry of the human system is of the greatest importance. Just a year previous to the beginning of the nineteenth century the urea which appears in well-formed crystals in the human organism was discovered by Fourcroy and Vauquelin. This fact, certainly, did not appear so strange, since crystalline matters had already been obtained from plants, but even in the beginning of the century the idea was still firmly rooted in the mind of the naturalist that these substances could only appear as the products of vital energy. This presented itself to the minds of men of that time as an entirely distinct force, which, independent of physical and chemical laws, manifested itself in a characteristic form in the organism. There is no discovery which has so often been quoted in the interest of the medical and other biological sciences as the observations of the chemist Wöhler who, in 1828, observed the formation of urea in a substance obtained outside of the system, namely, ammonium cyanide, by the transposition of atoms. But if we rightly consider this grand discovery, which completely refuted the followers of the theory of vital energy, it would still, perhaps, be possible, in spite of this discovery, to undertake the defense of the theory of vital energy as something beyond the laws of natural science, for neither Wöhler's synthesis nor the manner of formation of urea from carbonyl chloride and ammonia, or from ethyl carbonate and ammonia, or from cyanamide by hydration, or from ammonium carbonate, as well as from leucine and from other substances of the organism, gives any actual explanation of the formation of urea in the system. The synthetic product is identical with the product of the organism, but the synthesis, or rather the formation of urea in the body takes place in accordance with laws, the exact nature of which we do not fully know even at the present day. This is, indeed, the case with a large number of other substances derived from animals or plants. Although the chemical constitution of substances was constantly more and more exactly defined in the course of the nineteenth century, the manner of formation in the organism still remains hidden from us. We frequently find it stated that we must not simply compare the processes of the organism to the test-tube experiment of the chemist. There is no doubt that processes of metabolism take place within the body for which the synthesis performed outside of the organism gives no explanation. From my somewhat dissentient attitude in regard to the conclusions drawn from Wöhler's experiment, I might for a moment be thought to favor the view that the activity of the organism in the form of vital energy is beyond the laws of natural science, but that is not the case. Even if in synthetic experiments other means are employed than are available within the organism, the supposition is justified by the possibillty of synthesis, that the organic processes occur in accordance with purely physical and chemical laws, but that other conditions not present in test-tube experiments also play a part.

Here we must turn for a new mode of thought to Schwann's magnificent discovery of the animal cell. Through it the anatomical conception of the organism was placed upon an entirely different basis. As human tissues consist of cells, and the entire development of man results through cell activity, this must naturally lead us to assume that the purely chemical part of human existence takes place in as many cells as the individual possesses. That which in chemistry we describe as a reaction must, if we leave out of the question the chemical processes in the digestive tract, take place in small separate spaces, such as the chemist never employs for his experiments. The chemist does not usually assume that reactions occurring in such exceedingly restricted spaces differ from those which take place in the vessels used for his operations. It will be the task of the biologist to investigate whether this chemical action in the cells undergoes any modification through limitation of space.

I have been able to prove in the course of investigations on the "dead space in chemical reactions outside the organism" that powerful phenomena of friction take place here. This could not be definitely proven experimentally in the case of all reactions, but sometimes it could be shown that if the space inclosing the fluid be diminished, the reactions in comparison with those which occur in larger spaces are retarded if not completely arrested. The objection might be raised that in these experiments the retardation or arrest of reaction was generally due to the nearness of solid walls, but it was observed that the same phenomenon is noticed when the boundary of the fluid is only formed by surface tension, for the tense surface behaves like a firm elastic membrane toward the fluid, as is the case with many cells. The results showed that whenever the friction of the liquid increased, the chemical reaction was retarded. This hindrance of the reaction in small spaces, which differs in the case of different reactions, naturally permits the conclusion that, contrary to what happens in large spaces, in small ones entirely different reactions will result. Of course, this observation can only serve as the initial proof that the chemical action in the cells is unlike that which occurs in test-tube experiments. We see that here also the argument for the acceptance of the theory of vital energy which I pointed out to you as possible, is refuted.

As regards drugs and their absorption these chemical processes probably play an important part, for we observe that reactions occurring outside of the organisms do not take place within it, and on the other hand, combinations arise which are difficult to produce externally. Here we may mention, by way of illustration, the facility of decomposition of common salt into hydrochloric acid and alkali.

Moreover, I should like to remind you that, for example, in the toxicological processes in poisoning with carbolic acid we were entirely unable to foresee that the sulphuric acid of the organism forms with the carbolic acid a complex sulphuric acid, which, being non-poisonous, arrests the toxic effects of the carbolic acid.

Starting from this consideration, it does not appear strange that a number of substances which, even when much diluted, have a destructive effect on bacteria, manifest when taken up into the system no trace of disinfecting power, such as, for instance, phenol itself and corrosive sublimate in cases of anthrax.

The simplest example that the discovery of the cause of disease is by no means decisive in therapeutics may be seen in the development of the trichina. It is a humiliating fact that we are entirely powerless against this enemy. Even the female trichinae developing in the intestine after the consumption of meat infected with these parasites cannot be made innocuous by any known anthelmintic, and we are not even able to expel these intestinal trichinae by means of purgatives. The embryos wander irrevocably into the muscular tissues to destroy the organism, or by encapsulation remain permanently in the man or animal. Even in this process of calcification of the trichinae we are quite powerless to intervene.

The nineteenth century has been distinguished by the discovery of the causes of disease. But this does not give us means of "curing." As the history of therapeutics, however, shows that in the case of serious maladies, such as syphilis and malaria, the remedies have been found long before the recognition of their cause, we must continue to search for remedies independently of the causes of disease. So far the knowledge of morbific agents has been more important for prevention than for cure.

On the other hand, remedies like iodoform are entirely ineffective on bacteria outside the system, whereas after the entrance of this substance into the cells an energetic force is opposed to the invaders. As in every observation we must be careful not to draw too far-reaching conclusions, because the possibility of reactions taking place outside of the organism may also hold good within it, as, for instance, in the treatment of lead-poisoning. Therapeutics, thanks to Melsens, celebrated a great triumph here, for the iodine of the iodide of potassium administered in this disease combines with the lead united to the albumen molecules, forming iodide of lead, and can then leave the body dissolved in the alkaline juices of the organism, and thus bring about a cure.

It may be said, in passing, that in the case of many active substances specific chemical processes take place as are, for instance, seen in phosphorus poisoning. Phosphorus, though usually so easily oxidized, when absorbed, is not oxidized quickly enough by the oxygen of the cells; in the presence of turpentine oil, however, a transference of the oxygen occurs, and the phosphorus is more rapidly oxidized, combines with the oil of turpentine, and, as we must assume, forms turpentine-phosphoric acid, which is innocuous to the system. By the ingestion of oil of turpentine the organism can thus overcome the cause of illness.

Unfortunately we do not possess similar remedies for some other toxic morbific agents which are taken up by the cell.

Since for the progress of therapeutics it is necessary to consider the chemical and physical qualities of the body, therapeutics is naturally dependent upon progress in chemistry. Although, as has already been shown, pharmaceutical chemistry can be utilized for the benefit of medicine, the results of theoretical chemistry have not as yet become of much distinct importance for therapeutics. In the first half of the nineteenth century distinguished chemists occupied themselves with the laws of matter independent of biological processes. Various chemical and physical theories followed each other, and the theories propounded by Dumas, Gerhard, Williamson, and Kekulé eventually developed into van 't Hoff's stereochemistry, and in the physio-chemical researches. But these discoveries, though made outside the limits of biology, came to be of great importance to medicine when medical chemistry, fostered both by chemists and physicians, began its growth.

In the beginning of the century theoretical views in regard to drugs had to contend in part with the philosophical tendencies of those times, in part with the ill success which formerly attended the iatro-chemical and physio-chemical schools of physicians. Progress in the application of therapeutical measures was left to pure empiricism, and the view was accepted that what applied to food would also do for medicine; for we became acquainted with the use of coffee, tea, chocolate, potatoes, etc., not through theory, but simply through empiricism. This standpoint could be justified all the more because many important remedies, such as quinine, arsenic, and Peruvian balsam (which last substance has almost led to the disappearance of a contagious disease similar to leprosy in its terrible forms) became available to humanity purely through empiricism and not as the result of scientific investigations. Similarly, balneotherapy is of empiric origin; only recently, owing to the physiological researches of Winternitz and others and the application of physical chemistry, has it assumed the dignity of a separate branch of science. In consequence of a false point of view and empiricism the creative ideas of a Paracelsus were forgotten.

The progress in the chemistry of organic substances offered an opportunity to combine chemical and medical research, especially in the province of therapeutics.

I myself have had the pleasure of seeing that by this coöperation of medicine with organic chemistry an impulse has been given to therapeutics, which, in spite of a certain opposition, cannot again disappear from the sphere of research, an opinion which was held and expressed on the part of chemistry by the late A. W. von Hoffmann.

A good example is furnished by chloral, a drug formerly belonging to the chemical rarities, because Liebig's method of production provided no means of obtaining sufficient quantities for experimental medical research. This body was known as a chemical substance as early as 1832; but its intrinsic, therapeutic value was not discovered until the year 1868. It is in America more than anywhere else that these investigations have received the fullest appreciation. The use of chloral hydrate was based upon the idea that when taken up into the blood a splitting-off of chloroform takes place, as is the case outside the organism in the presence of all alkalies. This point has been the subject of much controversy. There can be absolutely no doubt that whenever chloral has had no soporific effect, a considerable quantity of urochloralic acid can be found in the urine, which must be traced back to the chloral. It is equally certain, however, that small quantities of urochloralic acid always are to be found in the urine after the administration of chloral. But it is just as true that the main therapeutic effect depends on the formation of chloroform. Only those who consider these principles will, as is shown by clinical experience, be able to observe chloral in the full unfolding of its effect. Shortly after its effect had become known the Glasgow clinician, Russel, proved that in conditions of excitement in typhoid fever, owing to the marked increase of the alkalinity of the tissues, small doses of chloral hydrate through their decomposition manifest the same effect as that produced only by large doses in similar conditions in other diseases. On the other hand, in gout the opposite happens. Even large doses do not produce the desired effect, since alkali is lacking for the decomposition.

But we cannot judge of all organic bodies from the standpoint of decomposition. Many take up substances from the organism, and since the discovery that benzoic acid becomes hippuric acid, and salicylic acid changes to salicyluric acid, it has been proved that the opposite of decomposition takes place with a number of drugs. Furthermore, it does not seem impossible that many substances unite with the disease-products formed in the organism. This hypothesis may be supported by the fact that the system itself produces an acid, such as glycuronic acid, which carries off foreign substances from the organism, such as camphor, phenol, etc., in the form of a double combination.

Since the time that chloral came into use, organic bodies have been particularly investigated. Owing to the tremendous amount of material, there has been a tendency to place reliance upon the chemical composition in making a choice, and it has been assumed that the chemical constitution stands in a certain relation to the action of a drug. Many experiments have been made in this direction. We do not wish to deny that such an influence occasionally exists; at any rate, we see that when the action of a given substance is known, changes in the molecule will produce a difference in action, and that by the introduction of certain groups certain definite changes in the effect may be expected. Among this group of bodies is antipyrin, in which changes in the side-chains leave the nature of the effect pretty much the same, even though new therapeutic advantages are obtained, as is best seen in pyramidon. A similar example is offered by veronal, lately suggested by E. Fischer as a soporific.

But it is as yet impossible to predict the effect of a chemical body from its constitution, unless a decomposition product of known action is formed, as in the case of chloral hydrate, or unless an active and well-known nucleus forms the basis of the substance. There are, of course, examples which point to the connection between constitution and effect, such as the difference between the action of bi- and trichlorinated aliphatic combinations. The trichlorinated bodies have a lethal influence on the heart; the bichlorinated bodies, such as chloride of ethyliden, only on the medulla oblongata. If trichlorinated butylaldehyde (butylchloral) be administered to an animal only an effect on the medulla oblongata is produced, in spite of the triple chlorination. The reason of this is that allylchloroform is formed in the organism, which, not being stable, splits up into dichlorallylen, which is a bichlorinated body.

Owing to the progress in chemistry medical science has been enabled to determine the relation which certain new drugs, by reason of their composition, bear to other established remedies of known constitution. This has been demonstrated by Gaetano Vinci in eucain, whose composition is analogous to that of cocain. Eucain is a drug which is truly fitted to replace cocain on account of its slighter poisonous nature, especially in the form of its lactic acid salt.

It has frequently been assumed that certain atomic groups in the molecule are the bearers of a special action, and that accordingly the bodies of a chemical series must exhibit a similar effect. That is, however, by no means the case, for even formic acid and acetic acid manifest markedly different biological properties. In alcohols the theory is founded on the presence of a certain chemical group, which is spoken of as the alcohol group. But we see this group appearing threefold in glycerine, and yet no physiological connection between the effect of common alcohol and of glycerine can be established.

In general we must confess, however, that we cannot as yet speak of a relation between constitution and effect, because what we call effect must be regarded as an influence on the different functions. Even if we consider the apparently simple mechanism of sleep, we must remember that it may be induced by an influence on the brain, or equally well by an action on the periphery. We cannot here enter into a physiological analysis of the processes taking place in the organism, but, as the above example shows, the most diverse parts of the system may be affected, so as to produce a similar result. Moreover, the different hypnotics, although fulfilling the same purpose, have an entirely different composition. On the other hand, when investigating the action of chemical substances we may always expect new results to become manifest by chance, for when Baumann was studying the effects of sulfonal it had never occurred to him that this body might possess soporific powers. We can best see the prominent part played here by chance in the introduction of salicylic acid into therapeutics. After Kolbe had succeeded in synthetically producing this acid, which is normally contained in the bark of the willow, he thought that it would exhibit disinfecting properties within the system by its decomposition. This decomposition does not, however, occur. Yet Kolbe's idea has led to the clinical application of this substance, and the valuable results obtained by Stricker from the use of salicylic acid in acute articular rheumatism, although it is not by any means a specific, have stimulated to continuous researches, most fertile for therapeutics, upon the various salicylic preparations.

It is not impossible that, starting from this small therapeutic field, the indications for the use of salicylic preparations may be greatly extended.

Even though the constitution of a chemical body gives us no firm basis for pharmacodynamic investigations, we can yet derive the most varied hypotheses from it. In pharmacodynamic research we may uphold the same principle which Claude Berhard expresses, namely, that by promulgating an hypothesis we are led on to experimental research, the solution of which may be of the greatest importance. G. Gore expresses his opinion in much the same way:

"A discoverer is a tester of scientific ideas; he must not only be able to imagine likely hypotheses, and to select suitable ones for investigation, but, as hypotheses may be true or untrue, he must also be competent to invent appropriate experiments for testing them, and to devise the requisite apparatus and arrangements."

The science of therapeutics quite properly does not follow a one-sided course, but seeks aid in all directions, and since the results of the exact natural sciences are not yet ripe to guide us clearly, we must take into consideration what has been gained by practical experience, for it would be a false principle to condemn popular medicines without examination. At the beginning of this lecture the successful application of digitalis was already mentioned. And here we must not entirely neglect the historical side of empiric observation. Frequently even the most absurd practices are based upon theory. When we turn away in disgust from the unclean excretory products of animals used in ancient times and by Asiatic nations, which we now regard as the very outcome of folly, we cannot ignore the fact that even this practice was founded on theory, though a false one. This is proved by Pliny, who tells us that animals eat and digest plants, but the medicinal part is not absorbed by the organism, but excreted, for which reason the feces contain substances curing human ills. These prejudices remained for centuries, as is proved by Paulini's book, published in 1697, but which can now be read only with disgust.

Such excretions as musk and castoreum, which are undoubtedly of value, should by no means be rejected. But particularly the nineteenth century has directed attention to the question whether the products of the organs themselves, or certain substances contained therein, might not be employed as remedies.

It was no easy task for Brown-Sequard to prove that the principles contained in the testicles of animals exercise a stimulating and exciting influence on the system. The discovery of spermin crystals, their occurrence in various organs, and the decidedly stimulating effect produced by these substances, reminded physicians that creatin, which had already been obtained from meat extract, had an effect similar to that produced by the salts of potassium on the animal body. This, as we may say, weak connecting link yet led to the further development of a principle in therapeutics. Medical chemistry has already succeeded in obtaining from the organism substances which may be of the greatest importance for therapeutics. You all know the effect of thyreoidin on the system. Obviously the active principles here are albuminoid bodies, the peculiarity of which has already been partly explained by Baumann in that iodine is one of their component parts. Probably no one would have imagined that this element must be regarded as one of the constituents of the human organism.

The very much studied question of the constitution of albumen will naturally lead to a more exact knowledge of the different kinds of albumen which are of value therapeutically and open a new field of observation to pharmacology.

The most surprising feature in the action of substances of the organs is presented by the constituent of the supra-renal capsule, adrenalin, not an albuminoid body, it is true. In order to better illustrate the importance of the new domain, the following pharmacodynamic experiment may be mentioned. Doses of cocain which are absolutely fatal to animals are easily borne in the presence of adrenalin without any injurious effect whatsoever. These substances, as they are found in the body of animals, are certainly of importance for the life-processes themselves. Taken from the animal body, they have the same effect as the human product, and can thus be employed as curative agents in man.

But medical chemistry had already undertaken researches which were not indeed utilized therapeutically at once, but came to exert great influence on therapeutics. In 1869, Zuelzer and Sonnenschein proved that alkaloidal bodies may be formed by the decomposition of the organic substances of the organism, and later on the theory of toxins was derived from this observation. This again has led to von Behring's remarkable and far-reaching theory of the anti-bodies formed in the organism.

How to make the substances obtained from the bodies of animals useful for therapeutics, depends upon the state of our physiological and chemical knowledge, and especially on the train of ideas arising in connection with these subjects. This can be seen, for example, in the case of the esters of cholesterin, the composition of which was already discovered by Berthelot, but not in connection with biological investigations. On the other hand, cholesterin esters had been observed in the form of wool-fat, and the impure product was used medically and cosmetically even in ancient times for its curative powers. It was proved that a functional significance as regards the animal organism must be attributed to cholesterin esters, for they are present in mammals, birds, and all creatures whose external surface is of keratinous character. They give luster to the skin, but act chiefly, so to say, as a protective varnish. The white substance of new-born children is therefore very properly termed cheesy varnish (vernix caseosa). It was formerly thought to consist of glycerine fat, but it is actually composed of cholesterin esters. The higher members of these esters are characterized by the physiological properties of wax. Gottstein has shown that this substance offers no food for microbes, is very stable, difficult to saponify, and not decomposed by the oxygen of the air' as are other fats. Thus it forms a protective matter, especially effective by reason of its waxy nature, and this has led to the production and application of therapeutic substances similar to cholesterin ester, as, for example, fetron.

The influence of pathological anatomy on therapeutics belongs entirely to the nineteenth century. To John Hunter in England and Bichat in France belongs the credit of freeing pathological anatomy from the brainless descriptive scientists, and of forming it into the necessary basis for every form of progress in therapeutics. From this time until Virchow's labors, the decisive importance of which is recognized impartially by all nations, pathological anatomy has exercised a great influence upon medical activity. Cellular pathology especially, in spite of all former battles and present attacks, will form the basis of every experimental and therapeutic observation, though some of the views concerning it may undergo modification through the progress of science, and opinions which Virchow himself could not accept may be brought forward again. The scientific question which appeared as a result of cellular pathology is the question of the cause and symptomatology of disease. Nothing can be more suitable in treating this question than to quote Virchow's own words:

"An elementary pathological process in the sense of cellular pathology appears thus: an external influence acts upon a living cell and alters it in a mechanical or chemical way. The external influence is the *causa externa*, or as we simply express it, *the cause of disease*: the altered condition is called *passio*, disease. If now, in consequence of the change undergone, an action (*actio s. reactio*) takes place in the living cell, this change is called a *state or irritation* (*irritamentum*), and the cause of disease irritants. If, on the other hand, no action ensues, if the condition is limited to the change "suffered" by the cell, we have to do with a mere disturbance (*laesio*) or *paralysis*. Since, however, the same cause can evoke irritation in one cell, merely a disturbance in another, and even paralysis in a third, we assume a certain difference of the internal arrangement to be the cause of this varying behavior. Thus we come to the internal cause or predisposition."

But these words, spoken in 1880, must be modified according to present experience. According to Virchow the *causa externa* is the cause of disease. The irritant acting upon the organism is *under all circumstances* the morbific factor according to this assumption. We do not wish to play with words. If, indeed, this foreign intruding agent produces a destruction of the cell-power or a morbid modification of it, it obviously must be regarded as the actual cause of disease. But when, for instance, we see that the invading body produces only an entirely local irritation, or, although capable of reproduction, as is the case with bacteria, no proliferation occurs, it becomes difficult to consider the same factor as the cause of disease in all instances. Virchow terms this phenomenon of indolence of the cell towards the intruder a want of predisposition; according to the school of bacteriologists, however, the cell is not a culture medium in the given case. We see from this explanation that Virchow himself assumes the cell-power to be variable, and we can quite logically and correctly say that by the term disease, *i. e.*, nosos, is designated that condition in which the external irritation can accomplish the defeat of the cell.

Von Hansemann has shown from a pathological and anatomical point of view that in cases of diabetes mellitus and other diseases the tubercle bacillus involves secondarily the lung. Von Hansemann calls this disposition, but we must certainly first of all term it "nosos," since it is a question of proved deviation from the normal.

This can also be illustrated by experiments. In a frog anthrax bacteria do not proliferate. As soon, however, as we place the animal in an incubator, *i. e.*, weaken the cell-power by heat, we are able to make the animal susceptible to the inoculation of anthrax. In this case the parasite is only a parasite of the diseased cell, and this kind of infection I have termed nosoparasitism. Thus we must describe as "nosos" the molecular change which we can no more observe through the microscope than we can the course of a chemical reaction, the outcome of which we judge only by the result.

The cell is subject to the same vital fluctuations as Brown has assumed for the organism. Brownonian theory has had no special value for practice, it is true, because at that time it was impossible to base a system of therapeutics on these observations so as to be of practical use. But it must be acknowledged that his theoretical deductions can be applied to the vitality of the cell. This theoretical explanation is under all circumstances of decisive importance for therapeutics, and already physicians are beginning to direct attention to this view in the study of therapeutics. Thus A. Menzer says: "The solution I have attempted to give to the question of the etiology of acute articular rheumatism is derived from the theory of a correctly interpreted nosoparasitism."

This question has grown to be of special importance for pulmonary phthisis. We cannot here enter into the subject of infection by tubercle bacilli; only one thing is certain, namely, that the bacillus is destroyed if the cells become healthy and only does harm when the cells are diseased. Even before the discovery of the tubercle bacillus this fact was proved by dietetic and open-air cures, as described in the excellent work of the two Doctors Williams, father and son, and Freund again has shown lately that the functions of the tissue of the lungs are impaired by abnormal immobilization of the first rib, and that then the tubercle bacillus can begin its work.

At the present day pharmacodynamics teaches that there are indeed drugs which do not merely act specifically upon a tissue, as phosphorus acts upon the formation of bone, but that there are also cell excitants, such as cantharidin, which, without themselves having any effect on the bacteria, can bring about the cure of diseased tissues, so that the nosoparasitic bacilli are destroyed.

But here begins a branch of science which, like the theory of immunity and serum therapy, occupied the end of the nineteenth century, and the waves of discussion still run so high that it is as yet unsuitable for an historical survey. It is sufficient to say that all the investigations of the present as well as of the past century afford us a guarantee that we are following the right road of progress in therapeutics, and assure us that in regard to the healing of disease there lie before us "infinite possibilities," to use the apt phrase which has been already employed in regard to the development of your country by Ludwig Max Goldberger, "Das Land der un-begrenzten Moeglichkeiten."

THE PROBLEMS OF THERAPEUTICS

BY SIR LAUDER BRUNTON

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THE subject of my lecture to-day is "The Problems of Therapeutics." My audience is a select one of persons interested in science and art. But science in these days has branched out so widely that it is impossible for any single person to be acquainted with every department of it, so that the terms used by a zoölogist may be unintelligible to a mathematician, or *vice versa.* There are some here whose researches have led them far into abstruse departments of science and if they were speaking I should gladly welcome a few introductory words from them on the very rudiments of their science in order to help me to understand a disquisition on the more advanced parts of their subjects.

Judging others by myself, I think they may be glad if I do the same, and I must beg the indulgence of those acquainted with medical science and its branches if this lecture should seem to be unnecessarily rudimentary. By therapeutics we mean the methods of healing. In the great staircase of St. Bartholomew's Hospital in London there is a large picture by William Hogarth representing the Good Samaritan. The poor traveler is seated on the ground, the Good Samaritan is pouring oil and wine into his wounds, while close at hand is a dog busily engaged in licking a cut which he has received in the fray. Both dog and man are engaged in solving, as far as they can, two of the primary problems of therapeutics, viz.: (1) how to relieve pain, and (2) how to restore health. For disease is want of ease, and health is only one form of the word "whole," by which we mean that a thing is entire and neither cut, broken, nor cracked. The closure of wounds is one form of restoring "wholeness" or "health" to the body, but it is by no means the only one, for the vital organs lie below the surface, and it is with disturbances of their functions, even more than with external wounds, that therapeutics, or the science and art of healing, is chiefly occupied. As exemplified in the dog or in the Good Samaritan, therapeutics is simply an art. Certain things are done because they have been found to do good before and so they are repeated again and again, but neither the dog nor the Good Samaritan understands the reason why their procedure is useful. It is only when we learn the reason why that an art becomes converted into a science. Therapeutics in its primitive form is one of the simplest of all the arts and is practiced by animals as well as by man, but as a science it is one of the most complex and most difficult of all because it requires a knowledge of the functions of the body in health, or physiology; of their changes in disease, or pathology; of the action of drugs upon the body, or pharmacology; and of chemistry, physics, and other sciences on which physiology, pathology, and pharmacology are based. Finally it requires the practical power of recognizing from the symptoms (in any individual case) the nature of the pathological changes present and the ability to apply the right methods of treatment in order to counteract these changes and heal the patient. It is evident that such complex knowledge as this must be very difficult of attainment, yet nevertheless the change of therapeutics from an art into a science is progressing with considerable rapidity. In a text-book on the subject which I published eleven years ago, I mentioned the use of quinine in ague as the best example of the art of therapeutics whereby we could cure a disease of which we did not know the nature by a remedy whose curative action we did not understand. Since that time, however, we have learned that ague depends upon the presence of a foreign organism in the body and that the benefits obtained from quinine are due to its poisonous action upon this intruder. This malarial parasite is only one of the many minute organisms which mar or destroy the health of the human body. Minute organisms or microbes are most useful in their proper place and without them the world would be uninhabitable because they are the natural scavengers which produce putrefaction in dead plants and animals and thus bring about their return to dust, fitting them for new life instead of allowing them to incumber the ground. But not content with this function some of them proceed to invade living beings, attacking not only the weak but even the strong, and by growing and multiplying within them weaken or destroy their hosts.

One of the great problems of therapeutics, then, is to defend the body from attacks of microbes. This may be done either (*a*) by weakening or destroying the microbes themselves or (*b*) by increasing the power of the organism to resist them.

It is convenient to speak of the body as a whole when we are discussing its invasion by microbes, but we must not forget that the body, like a country, is composed of many parts. The interests of the different parts are by no means identical, and while they generally act together for the common good they may not always do so, and either by their sluggishness and inaction or by their mischievous activity may do harm instead of good to the body as a whole. What is requisite for health is an harmonious action of all the different parts of the body, or as St. Paul very well puts it, "And thus all the body framed and knit together through that which every joint supplieth, according to the working in due measure of each several part, maketh the increase of the body unto the building up of itself" (Ephes. IV, 16, Revised Version), so "that there should be no schism in the body and that the members should have the same care one for another." No doubt in their long wanderings together Luke the beloved physician discussed physiology largely to Paul, and his expression is so good that I introduce it now.

Just as the people of a country is composed of individuals, so the body is composed of numerous cells. The whole class of microbes consists of isolated cells which are like a nomad population, each individual complete in himself, and all ready to form a swarm for attack and invasion. The cells which compose the body, on the contrary, are mostly fixed, and differ from each other in structure and function, but ought all to act together for the common good, like civilized people. Each cell lives in the fluid which surrounds it, blood or tissue juice, from which it takes what it needs for its own nutriment and pours back the products of its tissue activity which may be partly waste and partly manufactured products of the utmost utility.

In order to have a complete comprehension of therapeutic problems it is necessary that we should know something about the life of the cell, because the life of the whole body depends upon that of the cells which compose it, and the cure of disease and the preservation of life depend on our power to influence cell-life. The processes of life are to a certain extent the same in the human body as a whole, in the cells which compose it, and in the smallest living organisms or microbes as they are termed. They all digest and assimilate food, they all breathe, and they all excrete waste products. A knowledge of the processes of life in man helps us to understand them in low organisms and *vice versa*. The use of pepsin and pancreatin in indigestion is so common that almost everybody knows that these substances have the power of dissolving meat and that pancreatin converts starch into sugar. Everybody knows that these are got from the stomach and pancreas of animals and that it is by similar substances formed in our own digestive canal that we are able to dissolve the food we eat and render it fit for absorption. It has recently been found that pancreatic juice, as poured out by the gland which secretes it, is very slightly active, but it is made active by another ferment secreted from the intestine which is called enterokinase. The pancreatic juice contains several ferments; that which acts upon meat is called trypsine and in its inactive state it is called trypsogen. The action of the enterokinase on the trypsogen may be compared to that of a man who opens the blade of a knife and renders an instrument previously inactive very active indeed. If trypsine were absorbed into the blood unchanged it might digest the tissues themselves and it must be rendered again inactive. This seems to be effected by certain substances present in the blood which have a so-called "anti" action upon the ferments and render them again inactive. But though the digestive ferments might do harm if present in the blood in an active form and in large quantity, yet it is probable that all the cells of the body digest the food which is brought to them by the blood and tissue juices and break up this food for their own use by ferments which they contain themselves. Thirty years ago I advanced this view and supported it by the fact that I was able to extract from muscle by glycerine a substance which decomposed sugar. This observation received but very little attention at the time, but recently German literature is full of papers which support my views and confirm my results, although their writers apparently are ignorant of my work. Fifteen years ago, along with Dr. Macfadyen, I showed that bacteria not only excrete ferments by which the soil in which they are growing is digested, but that they are able to modify these ferments in accordance with the soil so as to digest either proteid matter or sugar. Curiously enough, within the last few years the pancreas in animals has been shown by Professor Pawlow to have similar powers.

No individual microbe has received so much attention as the yeast plant and no poison which is formed by any of them has done so much harm as the toxin or poisonous substance produced by yeast, for this toxin is alcohol, whose poisonous action has given rise to the term intoxication. The yeast-plant, when grown in sugar, excretes into it a ferment, invertase, which splits up ordinary cane-sugar or saccharose into two other sugars, dextrose and levulose. The yeast-plant may be separated from the solution of sugar by filtration, but the ferment which is already excreted will remain in the filtrate and may still continue to act on the sugar, just as pepsin may dissolve a piece of meat in a jar although the pig which produced it is dead and gone. But no alcohol will be formed by this excreted ferment. Alcohol is produced by something contained within the body of the yeast itself and its production was formerly supposed to be due to so-called vital action. It has now, I think, been proved that alcohol is produced by the action of a ferment which is contained within the body of the yeast-cell and is not excreted from it, so long as the cell is intact, but only passes out after the cells have been crushed into fragments. Whilst the cell is alive and intact it absorbs the sugar into its interior, breaks it up there, and forms the alcohol which is afterward excreted.

To make this clearer I may perhaps be allowed to use a very crude illustration and compare the ferment which is excreted by a bacillus or by yeast to the saliva which is said to be poured out by a boa-constrictor over its victim to facilitate its ingestion, while the ferments within the microbe may be likened to those in the stomach and intestine of the boa by which it effects the digestion of its prey.

Other microbes in like manner absorb nutriment and may form and excrete toxins, though both the nutriment and the toxins of bacilli in general differ from those of yeast.

To recapitulate what I have already said, we see therefore that

(1) Cells excrete ferments;

(2) They excrete poisons formed within their bodies; and

(3) When they are broken up they may liberate other ferments.

The ferments excreted by microbes apparently prepare the substance in or on which they are growing for assimilation, and the ferments within the cell-body decompose it further in the process of growth. It is probable that all cells, whether they be wandering microbes or cells coördinated in an organism, prepare and assimilate their nutriment by means of ferments, and Macfadyen and I found that not only have bacilli the power of excreting ferments, but apparently they are able to adapt the ferment which they excrete to the soil in which they are growing in much the same way as Pawlow has recently shown that the pancreas in animals modifies the ferments it forms according to the food which it is required to digest.

Not only is digestion carried on in the stomach and intestines by the ferments which are now so well known even to the general public, pepsin, pancreatin, etc., which dissolve the ingested food so that it is readily absorbed into the circulation and carried to every part of the body, but the other cells which compose the various parts of the body, muscles, nerves, and glands, probably carry on the functions of their life by means of ferments also. By means of these they alter and assimilate the various substances which are brought to them by the blood and juices of the body, and after having supplied their own wants they throw into the circulation the altered residue of their pabulum as well as the substances which they have themselves formed in their processes of growth. They probably repeat in fact what we have already seen to occur with yeast, which not only alters the sugar in which it grows by a ferment which it excretes, but also produces carbonic acid and alcohol by means of a ferment which remains within the yeast-cells so long as these are intact and only becomes liberated when these cells are broken up.

An excessive quantity of their own products is usually injurious to cells and too much alcohol will stop the growth of yeast. At the same time these products are frequently very nutritious for cells of a different sort and alcohol furnishes a most suitable pabulum for the organisms which produce vinegar. Vinegar in its turn is toxic to the microbe which produces it, but serves again as a soil for another which gives rise to a viscous fermentation. By the successive action of these ferments a solution of sugar may produce, first, alcohol, secondly, vinegar, and thirdly, ropy mucus. In this particular series each microbe produces a substance injurious to itself but useful to its successor. This is, however, not always the case because a cell may produce a substance not only injurious to itself but injurious to other cell, and alcohol in large quantity not only kills the cells of yeast but kills other cells as well. Similar conditions occur within living organisms where the cells composing the different parts are connected together and pass on the products of their life from one cell to another by means of the circulation of the blood and tissue juices. The secretions of one part may be, and indeed generally are, useful to other parts of the organism and so long as no part sins either by deficiency or excessive action the whole organism maintains a condition of health. But this is not always the case and health may be destroyed by (*a*) excessive, (*b*) defective, or (*c*) perverted action of one or more of the parts composing the body.

But health is even more frequently destroyed by the invasions of organisms from without. When these organisms fall upon an open wound they tend to grow and multiply rapidly, they secrete ferments and form poisons which enable them to destroy the tissues upon which they have fallen, and then finding their way into the circulation and being carried to all parts of the body they kill the animal which they have attacked.

One of the great problems of therapeutics then is to discover how best to defend ourselves against the attacks of microbes. In Hogarth's picture we see two methods by which this is done. The dog licks the wound it has received and thus removes from it any pathogenic organisms which may have lighted upon it. By insuring their absence it renders the wound *aseptic*, and *asepsis*, which is another word for excessive cleanliness insuring the absence of organisms, is one of the great measures by which the triumphs of modern surgery have been achieved. The treatment applied by the Good Samaritan to the wounds of the traveler is somewhat different, for he pours in wine the alcohol of which may hinder the germination of any microbes on the wound and thus prevent them from producing sepsis. This method, which in the hands of Lister has revolutionized surgery, is termed *antiseptic* as distinguished from the *aseptic* method used by the dog. There is no doubt that the aseptic method has got distinct advantages over the antiseptic method as applied to wounds because any substance which injures or destroys microbes will likewise injure the living cells of that part of the body to which it is applied. For this reason the aseptic method can only be employed to a very limited extent against microbes that have already entered the interior of the body, although it may sometimes be used, as for example in the treatment of dysentery, where repeated doses of saline purgative are now given so as to wash out from the intestinal canal the microbes which give rise to the disease, and even in ordinary diarrhea, where a purgative is employed to get rid of both the microbes and the poisons they have formed. More commonly, however, we have to depend on antiseptic methods either entirely or as an adjunct to asepsis, and a study of the action of various chemical substances on microbes has led to the introduction of a whole series of antiseptics and indeed to their actual synthetic formation, the problem to be solved being how to produce a body which will destroy the microbes most efficiently and at the same time will have the least injurious action upon the body of the animal invaded. Nor is it only inside the body that the action of antiseptics is desired. The search for preservatives for milk, meat, fish, vegetables, and fruit which shall be at the same time efficient and innocuous is one constantly going on at present. Asepsis is one of nature's methods of defense. When irritating substances get into the eye a flow of tears occurs to wash them away, from the nose and respiratory passages they are ejected by sneezing or by cough, and from the stomach or intestines they are removed by the vomiting and purging to which they themselves give rise. Even in the addition of preservatives in milk we seem to be following the example of nature because Andeer has found resorcin in which is an antiseptic in the fresh milk of cows. As Metchnikoff has shown, another method adopted by nature for removing and destroying infective microbes is to bring down upon them a host of white blood corpuscles, or leucocytes, which swallow up and destroy them. The more leucocytes that the organism can bring to bear upon the intruders the better chance it has of overcoming them. One problem, therefore, in therapeutics is to increase leucocytosis. At present we have comparatively few drugs that possess this power, cinnamate of sodium being perhaps the most active, but one of the problems to be solved is to find other substances which will do this to a greater extent than at present. The microbes on their part are ready to attack the leucocytes and fixed cells by means of toxic secretions or toxins and another of the defensive mechanisms which the organism adopts is to form *antitoxins*, as the antitodes to these toxins are generally termed. Some of these defensive bodies or alexins actually destroy the invading microbes themselves, while others simply neutralize the poisons or toxins they have formed. The nature of such defensive substances has been examined by Ehrlich to whom we owe much of our knowledge concerning them. It is very complicated and we do not yet know the precise mode of production of these antitoxins, but it is a curious fact that in many plants we find two poisons which are antagonistic in their action and which are to a certain extent antidotal to one another. Thus in jaborandi we have two alkaloids one of which, pilocarpine, stimulates secretion enormously, whilst the other, jaborine, paralyzes secretion, so that an extract of the jaborandi plant containing them in proper proportion might possibly appear inactive although it contained both alkaloids in considerable amount. The same is the case with poisonous mushrooms which contain a poisonous alkaloid, muscarin, which produces severe irritation of the intestine and an atropine-like substance which antagonizes it. Opium likewise contains alkaloids having very different actions, some being almost purely narcotic and others purely convulsant. The animal body seems to have a wonderful power of accommodating itself to the action of many poisons and this is very marked indeed in the case of opium. Many persons who begin with a small dose increase this gradually to an enormous extent so that they are able to take with impunity many times the ordinary lethal dose. The organism has a certain power of storing up antidotal substances within itself and Dr. Cash and I were able, by feeding animals with potash, to render them less susceptible to the poisonous action of barium, but except in the case of arsenic the organism seems to have but little power of becoming accustomed to inorganic poisons. It is different, however, in the case of organic poisons as shown by the resistance to the action of alcohol acquired by habitual topers and to morphine by habitual opium-eaters. A similar resistance may be acquired to snake-venom and to the toxins produced by microbes; and here it does not seem to be merely that the cells of the organism become accustomed to the poison, but that the organism forms an antidote, not only in sufficient quantity to neutralize the poison which is introduced, but actually in such superabundance that serum separated from the blood of an animal which has become immune to the action of snake-venom or of toxins will neutralize the effect of the venom or toxins in another animal. So great is this power that Sir T. R Fraser has found by inoculating an animal with gradually increasing doses that it may at length completely resist the action of fifty times the ordinary lethal dose of snake-venom, and in an experiment of M. Calmette I have seen an animal which had received the serum from such an immunized animal remain healthy and well, although another one which was inoculated at the same time and with the same dose of snake-venom was dying from the effect of the poison.

When horses are inoculated with successively increasing doses of the toxin of diphtheria, their blood acquires a high antitoxic power, and the use of the serum of such blood injected into patients suffering from diphtheria has robbed this disease to a great extent of its awful power. Hydrophobia is another disease which has been to a great extent deprived of its terrors by Pasteur's method of treatment. This differs in its plan from that used in diphtheria. In diphtheria the bacilli probably form a ferment which produces a deadly poison by exercising its digestive powers on the material it finds in the body. This poison is neutralized by the antidotal serum which is formed in a horse and is injected into the patient. In hydrophobia we have not been able to isolate the virus, but from its mode of action we suppose it to be a minute organism. This virus takes a long time to act in man, sometimes three weeks but usually six weeks, but when cultivated successively in rabbits it becomes very virulent indeed and acts much more quickly. It apparently finds its chief nidus in the spinal cord. When the cord is exposed to air the virus gradually becomes weakened and by injecting with an extract of very weak cord on the first day and with a stronger extract on each succeeding day the human body becomes accustomed to the virus and forms its own antitoxins. Thus by the time that the poison inoculated by the original bite of the rabid animal has time to develop its action the person has become immune.

One of the most important problems of therapeutics, therefore, is to render the human body immune against pathogenic microbes, against the ferments they form, and the toxins they produce. The two examples I have already given show how the toxins and possibly the ferments may be rendered innocuous by injecting antidotal sera and thus producing what is called "*passive immunity*," or by exciting the body to form antidotal substances itself and thus produce what is called "*active immunity*." Both these methods have been used, and are being used, in regard to other diseases, especially in those produced by micrococci of various sorts which give rise to suppuration and inflammations. One great difficulty in the way, however, is that the antidotal serum produced by one coccus is not always efficient against the disease produced by another, and so much is this the case that it would almost seem as if an antidotal serum would require to be made for each particular patient. Nor are the sera altogether innocuous themselves because their injection may be followed not only by annoying rashes on the skin but by general swelling of the body like that from advanced kidney disease, or by painful swelling of the joints almost like rheumatic fever. Another of the problems of therapeutics therefore is to obtain anticoccic sera which will not produce any unpleasant or dangerous symptoms.

Yet another is to confer on the tissues of the body the power of resisting or destroying microbes, their ferments, and their toxins, and thus protecting themselves or in other words acquiring immunity against the diseases which the microbes would produce. In considering this question it may help us if we remember that the products of our own digestion are poisonous and if the albumoses and peptones formed by the digestion of a beef-steak in the stomach were injected directly into a man's veins they would kill him, whereas, when changed by the cells of the intestine and liver in the process of absorption, they nourish and strengthen him.

The complexity of toxins and antitoxins is easily understood when we consider that they are probably all formed by the splitting-up of albuminous molecules and thus vary enormously just as the splinters of a broken glass vary in size, shape, and in power to puncture or cut.

In my address at Moscow, in 1897, I ventured to formulate the idea that immunity, natural or acquired, is nothing more than an extension to the cells of the tissues generally of a power which is constantly exercised during digestion by those of the intestine and liver. When microbes were just beginning to be recognized as the cause of infective disease, too much importance was attached to the mechanical effects which they might produce in the blood-vessels and tissues. As their mode of action became better known, this view was to a great extent given up, but though the small vegetable microbes, bacilli and cocci, have little injurious mechanical action, this is not the case with some minute organisms belonging to the animal kingdom, and such organisms of late years have become more and more recognized as causes of diseases. In elephantiasis the lymph channels become blocked by the ova of a small worm which inhabits the blood and thus the enormous swelling characteristic of the disease is produced. Within the last few years that dreadful scourge of tropical countries, malaria, has been discovered to be due to an animal parasite, and Manson and Ross have shown that the source of infection is the mosquito. By destroying mosquitoes or preventing their multiplication the disease can be to a great extent prevented, but we are still dependent upon bark, quinine, and arsenic as remedies to destroy the parasite and cure the disease. These are not invariably successful and we are still in want of medicines which shall infallibly destroy the parasite. The same is the case with other maladies where the infective microbe is of animal origin, as in sleeping-sickness, which is now attributed to a minute worm in the blood, or of vegetable origin as in ulcerative endocarditis, or of uncertain origin as in yellow fever.

But all these diseases excite much less attention than that which is perhaps more dreaded than any other in temperate climates, namely, cancer. We do not as yet know the pathology of this disease. It has been shown that in it the cells of the affected part multiply and grow in a different manner from that of ordinary tissues. They assume a reproductive type and grow independently of the tissues of the body in which they are situated.

We know that portions of carcinomatous growths may be carried by the blood-stream from one part of the body to another where they may act as new foci, but that they can only be transplanted with difficulty if at all from one animal to another. Thus it is evident that though their reproductive power is great their vitality is feeble. Therefore what one may hope for is, that though all the drugs hitherto tried have been powerless to prevent the life and growth of such tumors, yet something may yet be found which will attack and destroy them and nevertheless leave uninjured the healthy tissues by which they are surrounded. Lupus and rodent ulcer situated on the surface of the body have been successfully treated by the X-rays and ultra violet rays. These have little effect on deep-seated cancer. My friend, Sir William Ramsay, thinks, however, that the emanations from radium, which are to a certain extent soluble in water, might be administered with a view of destroying internal cancer, more especially as he has already found that they seem to have no injurious action when given to healthy animals. In the case of cancer it is certain that groups of cells take on a life of their own, and live independently of the wants of the organism as a whole. In some other diseases we find that entire organs become too active and thus injure the health of the whole body. One of the best examples of this is the thyroid gland which, when hypertrophied, produces, through the secretion which it pours into the blood, a curious set of nervous symptoms, dilatation of the vessels, palpitation of the heart, tremor, restlessness, excitement, and rise of temperature. In the disease known as Graves's Disease these symptoms exist and may possibly be aggravated by the condition of the nervous system which causes the characteristic protrusion of the eyeballs and may even be the cause of the swelling of the thyroid itself. But that most of the symptoms are really due to the action of the thyroid secretion is shown by the fact that they may all be observed after excessive administration of dried thyroid gland.

Here we have a toxin formed within the body by the over-action of one of its parts and at present we have no satisfactory antitoxin by which we can remove the symptoms, although supra-renal gland has an action somewhat antagonistic to that of the thyroid, and this gland or its extract when administered internally in cases of exophthalmic goitre sometimes appears to be beneficial. The case is very different, however, when, instead of being excessive, the action of the thyroid is deficient. When this occurs in adults the circulation becomes poor, the skin cold, the movements of the body and the action of the mind slow, the aspect becomes dull and heavy, and the features puffy and swollen. When thyroid gland or its extract is given, all these symptoms disappear and the patient becomes healthy for the time and usually remains so as long as the administration is continued. When deficiency of the thyroid occurs in childhood, the effect of treatment is still more manifest, for the child thus affected becomes stunted both in body and mind, is dwarfish, feeble, and idiotic. Under the administration of thyroid it grows rapidly and becomes strong and intelligent and indeed develops into a perfectly normal person. The cure effected by thyroid in such cretins is one of the most marvelous achievements of therapeutics and many attempts have been made with portions of other organs or extracts of them to supply material which is supposed to be absent in various diseases.

The first instance of this method of treatment, or *opotherapy*, as it is called, was, I believe, my employment of raw meat thirty years ago to supply the body with a ferment to use up sugar in diabetes.[1] The method was reintroduced by Brown-Sequard with more success, but it was not until the use of thyroid gland and its extract that the potentialities of the method became acknowledged. It is more than eighteen hundred years since the question was asked "Who can add a cubit to his stature?" and all this time we have remained ignorant of any plan by which we could add a single inch to a child's stature. Yet it now seems possible that by the use of thyroid gland and pituitary body, children, who would be otherwise stunted, may grow not only to the normal size but even above it.

So long, however, as we do not know the chemical nature of the substances which exercise such an extraordinary effect upon tissue change we shall not be able to deal with them so satisfactorily as we can now, in a way that was formerly impossible, regulate the temperature in fever. The clinical thermometer not only shows us the extent to which fever is present, but it enables us to stop the application of our remedies in time so as not to reduce the temperature to too great an extent. Cold water, ice, and diaphoretics were formerly the only antipyretic remedies, next salicin and quinine were introduced, then salicylic acid was made synthetically, and being cheap was used extensively, and within the last thirty years an increased knowledge of chemical methods and of the relationship between chemical constitution and physiological action has enabled numerous synthetic products to be formed, some of which may be more useful in certain cases than the original salicylate of soda.

A great many of these substances primarily intended to reduce the temperature have turned out to have a still more important action, namely, the relief of pain. There is no doubt that pain is useful as a warning against conditions which tend to destroy the organism and leads us to shun or remove these conditions to the great advantage of our health, but it is not always possible to do this and pain *per se* is one of the greatest evils that poor humanity has to bear. The introduction of antiseptics has completely revolutionized the art of surgery because it allows operations to be done with almost certain success which would in former days have almost inevitably proved fatal from unconscious contamination of the wound by disease-germs. But the greatest triumphs of surgery have only been rendered possible by the discovery of anesthetics. Previous to the work of Long, Jackson, Wells, Warren, and Simpson rapidity of operation was everything, and careful but long-continued manipulation was impossible because the long-continued pain of the operation would inevitably have killed the patient. Even the minor pains of neuralgia, neuritis, and headache, though not dangerous to life, are most distressing to the sufferer. Formerly there was almost no drug to relieve these excepting opium, while now we have phenacetin, antipyrin, phenalgin, and a host of others, and chemists are daily at work preparing new and perhaps even better pain-killers.

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[1] *British Medical Journal*, 1873.

Hardly, if at all, less distressing than pain is sleeplessness, and here again our powers of helping the patient have been enormously increased of late years. When I was a student almost the only hypnotics used were opium, henbane, and Indian hemp. The latter two were very unsatisfactory and practically one pinned one's faith on opium which had to be combined with tartar emetic in cases of fever. Then came the introduction by Liebreich of chloral, which was not only a great boon in itself but marked an epoch as one of the first instances of rational therapeutics, the application of a certain drug in disease because of its pharmacological action. Now we have any number of hypnotics, some of which are useful because they act on the nervous system itself and produce sleep without depressing the heart and can thus be given where the circulation is already weak, while others, like chloral, not only act on the cerebrum but lessen the force of the circulation, and by thus diminishing the flow of blood through the brain assist it to rest and aid the onset of sleep. Formerly when the circulation was too active the chief depressants were mercurial and other powerful purgative medicines, bleeding, tartar emetic, vegetarian diet, or partial starvation. Although these means may still be employed with advantage in proper cases, yet we have in addition a new set of remedies, viz., vaso-dilators, including nitrites, nitrates, and possibly a good many substances which dilate the vessels and lower the tension in the arteries, a tension which may be dangerous on the one side to an enfeebled heart and on the other to an atheromatous artery in the brain.

When the heart is failing we have a series of cardiac tonics and stimulants. Foremost amongst these, perhaps, may be put strychnine, the action of which on the heart was practically unknown when I was a student, and perhaps now it is hardly sufficiently recognized. At the time of which I speak, digitalis was looked upon as a cardiac depressant, and almost the only cardiac stimulant that was known was alcohol. Now digitalis, strophanthus, and a number of others are regularly used as cardiac tonics, and their power of contracting the vessels is also sometimes useful in removing dropsy. When this action is likely to be harmful to a weak heart, it may be lessened by the simultaneous administration of vascular dilators. We still, however, want drugs which will act only on the heart, or only on the vessels. We require medicines which will diminish the cardiac action and dilate the vessels for use in high tension, such as so often occurs in gout, and we need drugs which will make the heart beat more forcibly while they cause the vessels to contract and raise the tension in cases of debility.

But prevention is better than cure, and if by modifying tissue-change we can obviate the high tension and hypertrophy of the heart which so frequently lead to apoplexy, or the atheromatous condition of the vessels which leads to senile degeneration of the brain or premature old age, we shall lessen the necessity for either cardiac tonics or vascular dilators. Some authorities claim that they can do this by vegetarian diet, limited in quantity as well as in quality, while others would treat it by a diet almost entirely of meat with liberal potations of hot water. The subject of diet is one regarding which the most contradictory opinions prevail and there is a sad want of precise knowledge upon which to base dietetic rules. We may hope, however, that the investigation at present being conducted by Professor Atwater under the United States Government, combined with that which is being carried on under the auspices of the Carnegie Trustees, will furnish the information we need.

Time will not allow me to do more than mention aerotherapeutics, balneotherapeutics, and hydrotherapeutics; the rest-cure which is associated with the name of one of America's most brilliant and versatile sons, Weir Mitchell; massage and movements which Ling and his pupils, both in Sweden and elsewhere, have done so much to elaborate and which when rightly used may be so beneficial and wrongly used so harmful. For all these branches of therapeutics we require a more exact knowledge of their action and the rules for employing them, so that even those who have made no special study of them may employ them rightly in all diseases in which they may be of service.

Another method of cure consists in eliminating waste products from the body by rendering them more soluble and while limiting the water drunk would give lithia, piperazine, piperidine, and other substances which increase the solubility of uric acid. Before therapeutics can make much advance in this direction we must know more about the pathology of gout and tissue-metabolism generally, and we may then hope that not only will people be more free from the manifold symptoms that gout produces, but will live longer and the time of their activity, bodily and mental, will continue nearly as long as life itself. The power of increasing elimination of nitrogenous waste which urea possesses in a marked degree is shared by other substances belonging to the so-called purin group and day by day fresh bodies belonging to this chemical group are being made synthetically. Some of the new ones seem to have a greater power of eliminating waste than any we have hitherto had. The observations of Richardson, that alcohols vary in their action according to their chemical composition, and of Crum, Brown, and Fraser, that alteration in chemical constitution brings about a change in physiological action, are now beginning to bear rich fruit, and the synthetic preparation of remedies having different pharmacological properties along with our increasing knowledge of pathology gives us much hope for the future of therapeutics. More than two hundred years ago, Locke said: "Did we know the [mechanical] affections of rhubarb, hemlock, opium, and a man as a watchmaker does those of a watch, whereby it performs its operations, and of a file which by rubbing on them will alter the figure of any of the wheels, we should be able to tell beforehand that rhubarb will purge, hemlock kill, and opium make a man sleep." One of the great problems of therapeutics is not only to know (*a*) what drugs to use in order to obtain certain effects, but to know (*b*) how to make such drugs if we have not got them at hand. The struggle for existence does not occur only between man and beast, man and man, or nation and nation, nor even between individual beasts or plants. It takes place also between cell and cell, not only between those cells which we term microbes and the cells which form the human body, but even between those which form the different parts of the body itself.

The great object of this Congress is to unify knowledge, to render evident the similarity of the laws which govern phenomena of the most diverse character, and it is therefore interesting to find that the grand problem of therapeutics is for the cell what those of religion and sociology are for the man, viz., to learn how to regulate the environment of each cell or man in such a manner that the individual shall not work for his or its own good alone, but for that of others as well, and how to restrain or destroy those which are noxious. When we are able to regulate cell-life by food, air, water, exercise, inoculations, or medicines, we shall be able to relieve or remove weakness, pain, or distress, not only from the bodies but also from the minds of our patients, to maintain health, increase strength, and prolong life to an extent of which at present we can hardly dream.

SHORT PAPER

Dr. Reid Hunt, Pharmacologist of the United States Public Health and Marine Hospital Service, presented a paper to this Section on "The Relation of Acute and Chronic Alcoholism to some other Forms of Poisoning."

SECTION E—INTERNAL MEDICINE

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(*Hall* 13, *September* 23, 3 *p. m.*)

CHAIRMAN: PROFESSOR FREDERICK C. SHATTUCK, Harvard University.
SPEAKERS: PROFESSOR T. CLIFFORD ALLBUTT, F. R. S., University of Cambridge.
PROFESSOR WILLIAM S. THAYER, Johns Hopkins University.
SECRETARY: DR. R. C. CABOT, Boston, Mass.

THE HISTORICAL RELATIONS OF MEDICINE AND SURGERY

BY THOMAS CLIFFORD ALLBUTT

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IT was, I think, in the year 1864, when I was a novice on the honorary staff of the Leeds General Infirmary, that the unsurgical division of us was summoned in great solemnity to discuss a method of administration of drugs by means of a needle. This method having obtained some vogue, it behoved those who practiced "pure" medicine to decide whether this operation were consistent wiith the traditions of purity. For my part, I answered that the method had come up early, if not originally in St. George's Hospital, and in the hands of a house physician, Dr. C. Hunter; that I had accustomed myself already to the practice, and proposed to continue it; moreover, that I had recently come from the classes of Professor Trousseau, who, when his cases demanded such treatment, did not hesitate himself to perform paracentesis of the pleura, or even incision of this sac or of the pericardium. As for lack, not of will, but of skill and nerve, I did not intend myself to perform even minor operations, my heresy, as one traitorous in thought only, was indulgently ignored; and we were set free to manipulate the drug needle, if we felt disposed to this humble service. About this time certain Fellows of the London College of Physicians, concerned with the diseases of women, had been making little operations about the uterus, and meeting with but slight rebuke, they rode on the tide of science and circumstance, encroaching farther and farther, until they were discovered in the act of laparotomy; and rather in defiance than by conversion of the prevailing sentiment within those walls, they went on doing it.

Meanwhile the surgeons, emboldened by great events in their mystery, wrought much evil to the "pure" physicians; accusing them with asperity of dawdling with cases of ileus and the like until the opportunity of efficient treatment had passed away: nay, audacious murmurs were heard that such "abdominal cases" should be admitted into surgical wards from the first. Then, by dexterous cures, growing bolder and bolder, the surgeons went so far as to make a like demand for cases of tuberculous peritonitis, of empyema, and even of cerebral tumor. As thus the surgeons laid hands on organ after organ which hitherto had been sacred to "pure" medicine, and as indeed the achievements of surgery became more and more glorious, not only the man in the street but the man of the Hospital Committee also began to tattle about the progress of surgery and the diminution of medicine, until it was only by the natural sweetness of our tempers that the surgeon and the inner mediciner kept friends. At a dinner given on June 30 last to Mr. Chamberlain, in recognition of his great services to tropical medicine, this vigorous statesman said, "I have often heard that while surgery has made gigantic progress during the last generation, medical science has not advanced in equal proportion;" then, while modestly disclaiming the knowledge to "distinguish between the respective claims of these two great professions," he generously testified that "medical research assisted by surgical science has thrown a flood of light on the origin of disease, and that this at any rate is the first step to the cure of disease." Now Mr. Chamberlain is the first of English statesmen to ally himself actively with our profession; the first with imagination enough to apprehend the great part which medical science is playing in the world already, and to realize that only by medicine can vast surfaces of the earth be made habitable by white men, and those "great assets of civilization," the officers of our colonies, be saved alive. It seems to me, then, that the present is a critical moment in the relations of medicine and surgery, especially in England, where the two branches of the art have been separated so radically as to appear to be "two professions;" a moment when it is our duty to contemplate the unity of medicine, to forecast its development as a connected whole, and to conceive a rational ideal of its means and ends. But this large and prophetic vision of medicine we cannot attain without a thoughtful study of its past.

If, as from a height, we contemplate the story of the world, not its pageants, for in their splendor our eyes are dim, but the gathering, propagation, and ordination of its forces, whence they sprang, and how they blend this way and that to build the ideas and institutions of men, we may wonder at their creative activity, or weep over the errors and the failures, the spoliation and the decay, which have marred or thwarted them; and if we contemplate not the whole but some part of men's sowing and men's harvest, such a part as medicine, the keener is our sorrow and disappointment, or our joy and our hope, as we admire the great ends we have gained or dwell upon the loss and suffering which have darkened the way. "In the development of medicine," said Helmholtz, "there lies a great lesson on the true principles of scientific progress."

Pray do not fear, however, that to fulfill the meaning of the title of this address, I shall describe to you the history of medicine and the history of surgery, and on this double line compare and combine my researches; in the time allotted to me no such survey is possible. In the seventeenth century the handicrafts of anatomy, chemistry, and physiology so penetrated medicine that the separate influence of surgery is less easily discernible. My purpose, therefore, is to pass in review certain eminent features of the history of these departments of knowledge up to the end of the sixteenth century, and to compare them with a view to edification; your fear will be rather that I may tell my story with the unrighteousness of a man with a moral.

In his address on "Morgagni," at Rome, in 1894, Virchow said that medicine is remarkable in its unbroken development for twenty-five centuries; as we may say, without irreverence, from Hippocrates to Virchow himself. The great pathologist's opinion, however, seems to need severe qualification; if it be so, the stream has more than once flowed long underground. The discontinuity of medicine from Egypt to Crotona and Ionia is scarcely greater than from Galen to Avicenna; during which period, in spite of a few eminent teachers in the Byzantine Empire, it sank, in the West at any rate, into a sterile and superstitious routine.

Classical medicine, the medicine of the fifth century, B. C., is represented for us by the great monument of the Scriptures collected under the name of the foremost teacher of the age, Hippocrates; in genius perhaps the greatest physician of all past time. The treatises of the Canon may be divided into medicine, surgery, and obstetrics. The medical treatises, when read in an historical spirit, command our reverent admiration. Written at a time when an inductive physiology was out of reach, we are impressed nevertheless by their broad, rational, and almost scientific spirit. Medicine, even when not dominated by contemporary philosophy, has always taken its color from it; and the working physiology of Hippocrates was that humoral doctrine, originally derived from Egypt and the East, which, as enlarged by Galen, ruled over medicine till recent times. Hippocrates, while distinguishing between the methods of outward and inward maladies (φανερὰ καὶ ἄδηλα νοσήματα), taught that even for the inner, by careful sight and touch, laborious inspection of excretions, and so forth, many facts are accessible to methodical investigations; yet, as in inner diseases the field for inference is more spacious, the data even of direct observation fell the more readily into the scheme of the four humors, and by this doctrine were so colored that, although observed with a rare clinical insight, they were set in the frame of a fictitious pathology.

How was it then that the speculative side of the medicine of Hippocrates embarrassed him so little? Because the clinical method of the school was soundly based upon the outward maladies, where direct induction was practicable. No sooner indeed does an inward affection — an empyema for example — work outwards than the mastery of Hippocrates becomes manifest. What we separate as surgery, surgery which, from Guy to Paré, by clerks, faculties, and humanists was despised as vile, and from Paré to Hunter as illiberal, was in the age of Hippocrates, as in all critical epochs of medicine since that age, its savior.

If then our admiration of the inner medicine of Hippocrates, great as it is, is a relative admiration, an admiration of the historical sense, of his outer medicine our admiration is instant and unqualified. Little as the fifth century knew of inward anatomy, as compared with Alexandria about two centuries later, yet the marvelous eye and touch of the Greek physician had made an anatomy of palpable parts — a clinical anatomy — sufficient to establish a medicine of these parts of the body of which our own generation would not be ashamed.

In respect of fractures and luxations of the forearm, M. Pétrequin pronounces Hippocrates more complete than Boyer; in respect of congenital luxations richer than Dupuytren. Malgaigne again admires his comparison of the effects of unreduced luxations on the bones, muscles, and functions of the limb in adults, in young children, and before birth, as a wonderful piece of clinics. In Littré's judgment, the work of Hippocrates on the joints is a work for all time. On wounds Littré pronounces that the Hippocratic books must be pondered with deep attention; for they are founded on a wide experience, minute and profound observation, and an enlightened and infinitely cautious judgment. Permit me to call your attention, however, to certain of his counsels: That a wound be let bleed, in order to prevent inflammatory consequences; that if in fresh wounds healing by first intention may take place, suppuration or coction is the usual, and in less recent and in contused wounds the normal course; also that wounds should be treated with linseed and other poultices: counsels which, as we shall see presently, were to be as hotly contested in the thirteenth and fourteenth centuries as in the nineteenth. From amputation of the larger limbs he flinched, as did most if not all responsible surgeons down to Paré; for inner anatomy was ill-known, and ligature, even in wounds, made slow way, indeed, before Celsus, seems to have been unknown. Caries was not definitely distinguished from necrosis, but a case of disease of the palate with fallen nose irresistibly suggests syphilis. Of eye diseases we find much of interest; of obstetrical practice I must be content to say that it had reached a high standard; and to state once for all that when surgery flourishes obstetrics flourish.

It is by comparison of one part of the Hippocratic Canon with another that we learn how a strong grasp of inner medicine was attained by way of intense devotion to its inductive or surgical side. And this not by a mere empiricism; for it may have been from Hippocrates that Aristotle learned how by empiricism (ἐμπειρία) we perceive a certain remedy to be good for this person or for that — for Socrates, let us say, or for Callias — when he has a certain fever; but that by reason we discern the characteristic common to all these particular persons, wherein they react alike. In his *Book of Precepts* Hippocrates tells us that τριβὴ μετὰ λόγου is the basis of all medical knowledge. Now τριβή is primarily a grinding or rubbing; so the student must rub and grind at nature, using his reason at the same time; but his reason must be a perceptive and interpretative not a productive faculty, for he who lends himself to plausible ratiocination (λογισμῷ πιθανῷ προσέχων) will find himself ere long in a blind alley; and those who have pursued this course have done no enduring service to medicine. How soundly, for the time, this lesson was learned we see in the theoretical appreciation of these several faculties in the first chapter of Aristotle's *Metaphysics* and in the Sixth Book of the *Ethics*, where the senses, it is urged, cannot really be separated from the mind, for the senses and the mind contribute each an element to every knowledge. I am disposed to suggest that this method of observation, experience, and judgment was established first in medicine, because medicine is both practical and imperative; and, as Aristotle points out, concerned with the individual patient: to our art, then, may belong the honor of the application of positive methods to other sciences.

The chief lesson of the Hippocratic period for us is that, in practice as in honor, medicine and surgery were then one; the Greek physician had no more scruple in using his hands in the service of his brains than had Pheidias or Archimedes; and it was by this coöperation in the fifth century that the advance was achieved which in our eyes is marvelous. As we pursue the history of medicine in later times we shall see the error, the blindness, and the vanity of physicians who neglected and despised a noble handicraft. The clear eyes of the ancient Greeks perceived that an art is not liberal or illiberal by its manipulations, but by its ends. As, because of its ends, the cleansing and solace of the lepers by St. Francis and Father Damien was a service of angels, so Hippocrates saw no baseness even in manipulations, which obtained for his followers the name of *coprophagi;* where there is no overcoming there is no victory.

Between Hippocrates and Galen, an interval of some five centuries, flourished the great anatomical and medical schools of Alexandria. Our only important source, however, for the medicine of the Alexandrian period is Celsus, who lived in the reign of Augustus. In Celsus we find that the surgical and obstetrical sides of it had made farther and substantial progress. Celsus, perhaps not himself a practitioner, is sometimes vague in detail; still, beyond the Hippocratic surgery, we read of treatment in piles, fistula, rodent ulcer, eczema, fractures, and luxations; the nasal passages were cauterized for ozena; dropsies were systematically tapped; hernias were submitted to radical cure; plastic operations were undertaken, and the larger limbs were deliberately amputated, though only in extreme need, and often with fatal results by secondary hemorrhage and otherwise.

How active surgery was from Celsus to Galen, and how honorable and progressive a part of medicine, we know from the scanty records of Archigenes of Apamea, who also practiced in Rome, in the reign of Trajan. Galen calls him an acute but too subtle a physician; such of his subtleties, however, as are known to us — his distinction between primary and consequential symptoms for instance — are to his credit. He applied the ligature in amputations, and Antyllus applied the method to the cure of aneurism, which indeed Rufus seems to have done before him. Galen tells us where he got his "Celtic linen thread" for the purpose, namely, "at a shop in the Via Sacra between the Temple of Rome and the Forum." We learn also, from Oribasius, that Antyllus practiced extensive resections of bone in the limbs, and even in the upper and lower jaw.

Galen came to Rome under Marcus Aurelius. In the biological sciences this great physician stands to Harvey, as in physics Archimedes stood to Galileo and to that other great physician, William Gilbert; Galen was the first, as for many centuries he was the last, to apply the experimental method to physiology. He embraced the ancillary sciences, he opened out new routes, and he improved the old. Unhappily, his soaring genius took delight also in speculation; and it was not the breadth of his science, nor the depth of his methodical experiment, but the height of his visionary conceits which imposed upon the Middle Ages. Galen did not himself forget the precept of Hippocrates: To look, to touch, to hear (καὶ ἰδεῖν, καὶ θιγεῖν, καὶ ἀκοῦσαι); but he did not wholly subdue himself to the πεῖρα τριβικὴ — this toilsome conversation with troublesome facts. Galen did not make any great mark on surgery; his tracts on the eye are lost; but, so far as we know, his surgery was adopted in the main from the Alexandrians and from Soranus. However, Galen successfully resected the sternum for caries, exposing the heart; and he excised a splintered shoulder-blade: moreover, with all his bent to speculative reason, we have no hint that he fell into the medieval abyss of regarding surgery as unfit for a scholar and gentleman.

After Soranus and Galen medicine came to the evening of its second day, to the long night before the rise of the Arabian, Italian, and French surgeons of the twelfth, thirteenth, and fourteenth centuries.

In spite of the docile industry of Greek physicians of the Byzantine period, medicine gradually sank not into sterility only, but into degradation. The wholesome discipline of practical surgery had fallen off. Eastern folk, who bear heaven-sent sores with fatal stoicism, shrunk from the profane hand of man; and the tradition of Galen made for a plague of drugs which were least mischievous when merely superfluous. Rhazes, Albucasis, Avicenna the Arabian Galen, had entered by the door of the East into a great scientific inheritance, and, if they did little to develop surgery, it still was with them a grave and an honorable calling; with them medicine had not yet lost her right arm. The small benefits of the Church to medicine issued in a far greater treachery. The Greek of Ireland, and of England in the time of Bede, was banished by Augustine and the Benedictine missionaries; and the medicine of Monte Cassino, itself a farrago of receipts, in the monkish hostels of the West fell lower and lower. We have reason, however, to believe that even in the cloister some fair surgery was making way, when it was finally abandoned to the "secular arm" by the Council of Tours, in A. D. 1163; and books on surgery and midwifery began to disappear from the clerical libraries. The University of Paris excluded all those who worked with their hands; so that its students of medicine had to abjure manual occupation, and to content themselves with syllogisms and inspections of urine, often, indeed, without any inspection of the patient himself. From the University the Faculty of Medicine took its tone, and the Surgical Corporation of St. Come aped the Faculty. But by the expulsion of surgery from the liberal arts, and the societies of learned men, medicine herself was eviscerated; thus was made the pernicious bisection of medicine which has not yet spent its evil; the inductive foundations of the art were removed, and the clergy and the faculties, in France and England at any rate, devoted all their zeal to shoring-up the superstructure. Surgery saw its revenge, its bitter revenge; but in the ruin of its temple. In the thirteenth and fourteenth centuries surgery, hated and avoided by medical faculties, scorned in clerical and feudal circles, began in the hands of lowly and unlettered men to grow from a vigorous root; while inward medicine, withdrawing itself more and more from the laboratory of nature, hardened into the shell which till the seventeenth century was but a counterfeit. The surgeons of the thirteenth, fourteenth, and fifteenth centuries, reared in humble apprenticeships, not illiterate only, but forbidden the very means of learning, lay under heavy disadvantages; yet, such is the virtue of practical experience, inductive method, and technical resource, that by them the reform of medicine was made. Towards the end of the fifteenth century, indeed, this progress had slackened, soon to be reinforced, however, by new and urgent problems, not of the schools, but of direct rough and tumble with nature. Of these new problems, of which Paré became the chief interpreter, new epidemics and the wounds of firearms were the chief.

In medicine from the twelfth to the eighteenth centuries Italy led the world; in the schools of Salerno, Naples, Bologna, Padua, was contained a strong lay and imperial tradition which gave pause to clerical ascendency. Bologna, until the predominance of her law school, was indeed a large and plenteous mother to medicine in its full orb; but already in Salerno far-seeing men had begun to dread the divorce of surgery from inner medicine. The important Salernitan treatise of the end of the twelfth century, *The Glosses of the Four Masters on the Surgery of Roger and Roland,* edited by Daremberg and de Renzi, begins with a lament on the decadence of surgery, which they attribute to two causes; namely, the division of surgery from medicine, and the neglect of anatomy. By the wisdom of Bologna and Naples, where chairs of surgery were founded, this ill-starred divorce was postponed; in his University of Naples indeed Frederick the Second made it a condition that surgery should be an essential part of medicine, should occupy as long a course of study, and should be established on anatomy "without which no operator can be successful."

Roger's *Practica Chirurgiae* was written in 1180, and though of course it rests upon the traditional surgery of his day, there are not a few points of interest in the book, such as certain descriptions suggestive of syphilis. For hemorrhage Roger used styptics, the suture, or the ligature; the ligature he learned no doubt from Paul of Egina; but Roger, like most or all qualified physicians of the period, was a "wound-surgeon" only, that is, he did not undertake the graver operations. He was in favor, as a rule, of immediate extraction of weapons from their wounds; but in these wounds, even after extraction, he encouraged suppuration by stimulating applications within and around them, and dressed them with ointments on lint. To these points, especially to the promotion of pus, and the unctuous dressings, permit me again to draw your attention; for we enter now upon a surgical controversy which, pale reflection as it may be of the great surgical dayspring of the nineteenth century, is, historically speaking, of singular interest.

Hugh, of Lucca, says Malgaigne, is the first of the surgeons of modern Europe whom we can cite with honor. This tribute is a little strained; we may say, however, that of these honorable ancestors Hugh seems to have been a chief. I say "seems to have been;" for Hugh is even a dimmer giant than Roger or Roland. We know that he was born of honorable family about the middle of the twelfth century; that he served as surgeon in the campaigns, and was present at the siege of Damietta; but of writing he left not a line. Such vision as we have of him we owe to his loyal disciple, probably his son, the Dominican Theodoric, Bishop of Cervia, and master of Henry of Mondeville. He completed his "surgery" in 1266, but his life was almost coterminous with the thirteenth century. What was Theodoric's message? He wrote thus: "For it is not necessary, as Roger and Roland have written, as many of their disciples teach, and as all modern surgeons profess, that pus should be generated in wounds. No error can be greater than this. Such a practice is indeed to hinder nature, to prolong the disease, and to prevent the conglutination and consolidation of the wound." In principle what more did Lister say than this? Henry of Mondeville made a hard fight for the new principle, but the champions of Galenism and suppuration won all along the line; and for five following centuries poultices and grease were still to be applied to fresh wounds, and tents, plastered with irritants to promote suppuration, were still to be thrust into the recesses of them, even when there was no foreign body to be discharged. If after all this, erysipelas set in — well, says Henry, lay it at the door of St. Eligius! Hugh and Theodoric for the fresh wound rejected oil as too slippery for union, and poultices as too moist; they washed the wound with wine, scrupulously removing every foreign particle; then they brought the edges together, forbidding wine or anything else to remain within. Dry and adhesive surfaces were their desire. Nature, they said, produces the means of union in a viscous exudation, or natural balm as it was afterwards called by Paracelsus, Paré, and Würtz. In older wounds they did their best to obtain union by cleansing, desiccation, and refreshing of the edges. Upon the outer surface they laid only lint steeped in wine. Powders they regarded as too desiccating, for powder shuts in decomposing matters; wine, after washing, purifying, and drying the raw surfaces, evaporates. The quick, shrewd, and rational observation, and the independent spirit of Theodoric, I would gladly illustrate farther did time permit; in passing, I may say that he was the first to notice salivation as the result of administration of mercury in "skin diseases."

Both for his own merits, and as the master of Lanfranc, William Salicet was eminent among the great Italian physicians of the latter half of the thirteenth century. Distinguished in surgery, both as practitioner and author, he was also one of the protestants of the period against the division of the craft from inner medicine; a division which he justly regarded as a withdrawal of medicine from intimacy with nature. Like Lanfranc and all the great surgeons of the Italian tradition, and unlike Franco and Paré, he had the advantage of the liberal university education of Italy; but, like Paré and Würtz, he had also large practical experience in camp, hospital, and prison. His *Surgery* contains many case-histories. He discovered that dropsy may be due to a "durities renum;" he substituted the knife for the abuse of the cautery by the followers of the Arabs; he pursued the investigation of the causes of the failure of healing by first intention; he described the danger of wounds of the neck; he forwarded the diagnosis of suppurative disease of the hip, and he referred chancre and gangrene to "coitus cum meretrice."

The *Chirurgia Magna* of Lanfranc of Milan and Paris, published in 1295-96, was a great work, written by a reverent but independent follower of Salicet. He distinguished between venous and arterial hemorrhage, and generally used styptics; white of egg, aloes, and rabbit's fur was a popular styptic in elder surgery, though in severe cases ligature was used. Learned man as he was, Lanfranc saw the more clearly the danger of separating surgery from medicine. "Good God!" he exclaims, "why this abandoning of operations by physicians to lay persons, disdaining surgery, as I perceive, because they do not know how to operate . . . an abuse which has reached such a point that the vulgar begin to think the same man cannot know medicine and surgery. . . . I say, however, that no man can be a good physician who has no knowledge of operative surgery; a knowledge of both branches is essential" (*Chirurgia Magna*).

Henry of Mondeville, of whom we hear first in 1301, as surgeon to Philip the Fair, was for the most part a loyal disciple of Lanfranc, and, aided as it would seem by Jean Pitard, also surgeon to the King, attempted for wounds to introduce the new methods of Hugh and Theodoric; for his pains he exposed himself to bad language, threats, and perils; and "had it not been for Truth and Charles of Valois," to far worse things. So he warns the young and poor surgeon not to plow the sand; but to prefer complaisance to truth, and ease to new ideas. I may summarize, briefly, the teaching of Henry on the cardinal features of the new method:

Wash the wound scrupulously from all foreign matter; use no probes, no tents — except under special circumstances; no oily nor irritant applications; avoid the formation of pus, which is not a stage of healing, but a complication; do not, as Galen teaches, allow the wound to bleed with the notion of preventing inflammation, for you will only weaken the patient's vitality (*virtus*), give him two diseases instead of one, and foster secondary hemorrhage; distinguish between oozing hemorrhage, hemorrhage by jets, and that which pumps out of an inward wound, using for the first, styptics, and for the last two the cautery, or, where practicable, digital compression for not less than a full hour; when your dressings have been carefully made, do not interfere with them for some days; keep the air out, for a wound left in contact with the air suppurates; however, should pain and heat arise, open and wash out again, or even a poultice may be necessary, but do not pull your dressings about — nature works better alone; if first intention fail, she may succeed in the second, as a jeweler, if he can solder gold to gold does so, if not, he has to take to borax; these resources, however, we learn well, not by arguing but by operating. By the new method you will have no stinks, shorter convalescence, and clean, thin scars. In wounds of the neck he says that alterations of the voice suggest implications of the larynx. When using the word "nature," he freely admits that the word is an equivocal one, but he would speak of her allegorically as a lute-player to whose melodies the physician has to dance. Again he says: "Every simple wound will heal without any notable quantity of pus, if treated on Theodoric's and my instructions. Avoid every cause of formation of pus, such as irritating applications, exposure to air, high diet, edema, local plethora. Many more surgeons know how to cause suppuration than how to heal a wound." Now let me remind you that, until Hugh of Lucca, the universal doctrine was that suppuration or coction is necessary; and that if it does not set in, it must be provoked.

The greatest of the French surgeons before Paré was Guy of Chauliac, who flourished in the second half of the fourteenth century. He studied in letters and medicine at Toulouse and Montpellier; in anatomy at Bologna. The surgeon, ignorant of anatomy, he says, "carves the human body as a blind man carves wood." The Arabs and Paris said: Why dissect if you trust Galen? but the Italian physicians insisted on verification. Guy was called to Avignon by Clement VI. During the plague of 1348 he stayed to minister to the victims, and did not himself escape an attack, in which he was ill for six weeks. His description of this epidemic is terrible in its naked simplicity. He gave succor also in the visitation of 1360.

His *Chirurgia Magna* I have studied carefully, and do not wonder that Fallopius compared the author to Hippocrates, and that John Freind calls him the prince of surgeons. The work is rich, aphoristic, orderly, and precise. Guy was a more adventurous surgeon than Lanfranc, as was Franco, a later Provençal, than Paré. He did not cut for stone, but he operated for radical cure of hernia and for cataract; operations till his time left wholly to the wayfaring specialists. In Guy the critical spirit was awake. He scorns the physicians of his day, "who followed each other like cranes, whether for fear or love he would not say." In respect of principles, however, Guy was not infallible. Too sedulous a disciple of Galen, he was as a deaf adder to the new message of Hugh, Theodoric, and Henry; and not only was he deaf himself, but, as the authoritative master of the early renascence, he closed the ears of his brethren and successors, even to the day of Lister.

This vigorous life which surgery gave to the medicine of the thirteenth and fourteenth centuries was stifled in the West by the pride and bigotry which, culminating in the Council of Tours, had thrust surgery down into the ranks of illiterate barbers, reckless specialists, and adventurous charlatans. In Italy, however, the genius and bent of the people for art as well as for philosophy, and the ascendency of the secular element in the universities, still kept surgery in its place as "the scientific arm of medicine."[1] Thus in Italy of the fifteenth century surgery did not droop as it did in the West; if it slumbered for a spell, it soon awoke again, refreshed in the new Hellenism. Pietro di Argelata (d. 1423), Doctor of Arts and Medicine, and professor of Bologna, wrote an excellent *Surgery* full of personal observation; and perhaps for the first time, was frank about his own mistakes. Bertipaglia, another great Paduan professor, flourished a little after Argelata, but was a man of less originality. Argelata followed the lead of Henry and Guy in some bolder adventure in operative work as distinguished from mere wound-surgery, and was himself a learned and skillful practitioner.

In the midst of the mainly Arabist professors of medicine of the fifteenth century arose Benivieni, the forerunner of Morgagni, and one of the greatest physicians of the late Middle Ages. This distinguished man, who was born in 1448 and died in 1502, was not a professor but a Doctor of Medicine, a man of culture and an eminent practitioner in Florence. Although born in the new platonism, he was, like Mondeville, one of those fresh and independent observers who surrender to no authority, to Arab nor Greek. Yet for us Benivieni's fame is far more than all this; for he was the founder of the craft of pathological anatomy. So far as I know, he was the first to make the custom, and to declare the need of necropsy to reveal what he called not exactly "the secret causes," but the hidden causes of diseases. Before Vasalius, Eustachius, or Fallopius were born, deliberately and clear-sightedly he opened the bodies of the dead as keenly as any pathologist in the more spacious times of Morgagni, Haller, or Senac, or of Hunter, Baillie, and Bright. Among his pathological reports are morbus coxae (two cases), biliary calculus (two cases), abscess of the mesentery, thrombosis of the mesenteric vessels, stenosis of the intestine, "polypus" of the heart, scirrhus of the pylorus, ruptured bowel (two cases). He gives a good description of senile gangrene. Thus necropsy was first brought into practice to supplement the autopsy which the surgeon had long practiced in the living subject.

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[1] A phrase which Sir John Burden Sanderson once used in my hearing.

It would be unjust to forget that in the latter half of the fifteenth century Paris admitted some reforms; celibacy for physicians was abolished, and with it diminished the allurements of prebends and rectories, and the pernicious practice of the "médecins reclus" who did not visit patients nor even see them, but received visits from ambassadors who brought gifts and vessels of urine, and carried back answers far more presumptuous than the well-known counsel of Falstaff's physician. Still not only was reform in Paris very grudging, but it was capriciously favored and thwarted by the French court. The faculty denied to St. Come "esoteric" teaching, diagnosis, and the use of medical therapeutics; a jealousy which ended in the physician being requested to do little more than write the prescription. Aristotle was quoted as unfavorable to the "vulgarizing of science." Joubert was attacked for editing Guy in the vernacular. Fortunately the surgeons were carried into the field of battle, a far better school than the Paris Faculty.

Thus it was that in the opening of that great century in the history of the human mind, the sixteenth century, we find Italian medicine still in the van, until the birth of the great French surgeons, Franco and Paré, and of Gersdorff and Würtz in Germany.

Franco, like Paré, was no clerk; he came of a class lower even than that of Paré and the barbers, the wayfaring class of bonesetters, oculists, plastic operators, and cutters for stone and hernia; "runagates," as Gale calls them. Thus dangerous visceral operations, and those on the eye, which but too often were swiftly disastrous, fell into the hands of wandering and irresponsible craftsmen, men of low origin, and too often ignorant, reckless, and rapacious. As the truss was a very clumsy instrument, at any rate till the end of the seventeenth century, the radical cure of hernia was in great demand. It is not the least of the merits of Franco that he brought these operations within the lines of responsible surgery, and thrust them into the ken of Paré and Fabricius. This illustrious Provençal surgeon — "*ce beau génie chirurgical*," as Malgaigne calls him, in declining the task of entering upon so full a life — was born about 1503. He began as an apprentice to an operating barber and hernia specialist. He had no more "education" than Paré or Würtz, and he was spared the misfortune of a speculative intellect. He picked up some anatomy, educated himself by observation, experience, and manipulation, and as a simple operator or "Master," won considerable renown. As upright and modest as Paré, though he never attained Paré's high social position, he submitted to call in the physician, and took his quiet revenge in the remark that the physicians did not know enough to distinguish good surgery from bad. Nicaise says roundly, "No surgeon made such discoveries as Franco; for hernia, stone, and cataract he did much more than Paré." Whether from incapacity or the brutality of habit, during the Middle Ages and down even to the middle of the seventeenth century, it had been the custom in operating for hernia to sacrifice one or even both testicles, an abuse against which Franco took successful precautions, for he proved that the canal could be closed and the ring sutured without castration. In irreducible inguinal hernia he distinguishes between opening and not opening the sac, and describes adhesions of sac and intestine. From him, indeed, dates the rational operation for strangulated hernia, and in strangulated scrotal hernia he founded the method. Paré, and after him Petit, condemned the ablation of the testicle, which procedure, however, many surgeons thought quite good enough for priests; and Paré gives credit to Franco for these advances, though Fabricius does not even mention them. On the interesting subject of plastic operations, which attained a remarkable vogue in the Middle Ages, and were but restored by Tagliacozzi, I have not now time to speak.

The very eminence of Ambroise Paré encourages if it does not command me to be content with a few words of commemoration. Himself of humble origin, he won for surgery in France a social place and respect it had never attained before. Born in 1517, he became a barber's apprentice in the Hôtel Dieu, whence he followed the campaign of Francis I against Charles V. As he could not write a Latin treatise, his admission to St. Come was of course opposed by the Faculty; but Paré stoutly declared that the vernacular tongue was essential to the progress of medicine. Riolan the elder, who had taken part in the opposition, wrote a tract on the other side, in 1577, with the following insolent title: *Ad impudentiam quorundam Chirurgorum qui medicis aequari et chirurgiam publicè profitere volunt pro dignitate veteri medicinae apologia philosophica.* Now at this time Paré was 60 years of age and surgeon to the King. If in comparison with Paré, Haeser treats Franco somewhat slightingly, and if in some respects Paré may not be lifted far above some of his great Italian contemporaries, such as Maggi, Carpi, or Botallo, yet taken all around the founder of modern surgery surely surpasses all the physicians of his time as an independent, original, and inventive genius, and as a gentle, masterly, and true man. Yet I am often surprised to see, even to-day, the invention of ligature of arteries attributed to Paré, whose surprise, if our journals have an astral shape, must be greater still, seeing that he himself refers the ligature to Galen. The attribution is of course a legend. Malgaigne discreetly claims no more for Paré than the application of the ligature from wound-surgery to amputations; but in my opinion even this claim goes beyond the truth of history. Celsus speaks of the ligature as an ordinary method in wounds; from Oribasius we learn that Archigenes of Apamea even tied vessels in amputation, after fixing a tight band at the root of the limb. It seems probable that, unless performed with modern nicety, secondary hemorrhage must have been frequent; indeed in 1773, Petit deliberately discarded the ligature, as Franco and Fabricius had done before him. Military surgeons considered even Paré's "ligature en masse" too delicate a method for the battle-field. It is a more intelligent service to this great man to point out that the ligature and other operative details were no singular devices, but orderly steps in a large reform of method in amputation, a reform made imperative by the ravages of firearms, ravages which could not be covered up with Galenisms.

It is the privilege of the historian to make light of time and space; and it is not easy to leave Paré and his times without some reflection upon the great German surgeons, Brunschwig, Gersdorff, and Würtz, who, like him, were concerned with the effects of firearms. In Italy in the sixteenth century surgery was somewhat on the wane, but in Germany Würtz, in the freshness and originality of his mind and in his freedom from scholastic convention, reminds us of Paré.

Paracelsus (born 1491) was a surgeon and no inconsiderable one. Had this extraordinary man been endowed with a little patience he would have been a leader in wound-surgery, though, like Würtz, he was not an operator. He pointed out not only the abuse of the suture by the surgeons of the day, but also that suppuration is bad healing, for, if left to herself, nature heals wounds by a natural balm, a phrase which Paré adopted. In his *Grosse Wündarznei* he says he began at the surgical because it is the most certain part of medicine, and time after time he rebukes those who withdraw medicine from surgery. Brunschwig was indeed the first surgeon to write upon the surgery of gunshot wounds with any fullness or precision. He held, however, as Vigo after him, that a gunshot wound was a poisoned wound; and, to eliminate the poison by free suppuration, used the medicated tents, or in case of thorough penetration, the setons which were to arouse the angry antagonism of Würtz.

Felix Würtz, like Franco and Paré, had also the good fortune to escape a scholastic education; he was lucky enough, however, to enjoy the liberal education of Gesner's friendship, and to listen to the fiery disputes of Paracelsus. Gifted with an independent and penetrating mind, he is as fresh and racy as Henry of Mondeville had genius enough to be in spite of the schools. Like all his compatriots, he wrote in the vernacular; and for its originality and conciseness, Würtz's *Practica*, published in 1563, stands in a very small company. Had he known as much anatomy as Paré, his defect in which he bewails, he might have been as great a man, for his clinical advances were both new and important. He protests against the kind of examinations for practice held in some cities where candidates patter off cut and dried phrases like parrots, while apprentices "play upon the old fiddle the old tune continually." By setting his face against cataplasms and grease, he made for progress, though neither he nor Paré attacked suppuration in principle as Theodoric and Henry had done. His chief title to fame, a fame far less ripe of course than that of Sydenham, but, as it seems to me, not unworthy to be remembered beside it, lies in his clinical acumen, and especially in his conception of wound infections and their results. His description of diphtheria is especially remarkable.

While surgeons from generation to generation were making the solid progress I have indicated, what were the physicians about? Now, of the fantastic conceits they were spinning, of the gross and blundering receipts with which they stuffed their books, I have not time to speak; fortunately, history has but too well prepared you to dispense with this side of the story. One example I will give you: In the sixteenth century the air was rent by the clamor of physicians contending in two camps with such ardor and with such acrimony that the Pope, and even Charles the Fifth, interfered — and on what momentous principle? Whether, in such a disease as pleuro-pneumonia, venesection was to be practiced on the same side as the disease or on the opposite side? Brissot, who questioned the Galenical tradition in this matter, was declared by the Emperor to be a worse heretic than Luther. Unfortunately for Imperial medicine, if indifferently for science and the public weal, it came out, on the recovery of the text of Hippocrates, that Brissot had happened to be on the side of the father of medicine.

England, if by England we mean no more than the Isles of Britain, makes no great show in medieval or renascence surgery. Arderne was probably a far better surgeon than Gilbert or John of Gaddesden; but he is little more than a name. Nor does it do to peruse Thomas Gale (1507-1586?) after Mondeville, Guy, Paré, Würtz, or Maggi. In the *Wounds Made by Gonneshot*, the third part of his *Surgery*, lies Gale's merit, that he also withstood "the gross error of Jerome Brunswicke and John of Vigo, that they make the wound venomous."

With the sixteenth century my survey must end; from this time medicine entered upon a new life, upon a new surgery founded on a new anatomy and on a new physiology of the circulation of the blood and lymph. These sciences, thus renewed, not only served surgery directly, but by the pervading influence of the new accuracy of observation, and the enlargement of the field of induction, also indirectly modified the traditional medicine of physicians unversed in methods of research, as we observe in the objective clinical medicine of Sydenham. Our physiologists tell us that destruction is easy, construction difficult; but in the history of medical dogma this truth finds little illustration. So impatient is the speculative intellect of the yoke of inductive research, so tenacious is it of its castles in the air, that no sooner did Harvey, by revealing the mechanics of the circulation, sap the doctrines of the schools, than some physicians instantly set to work to run up the scheme of iatro-physics; others to build a system of iatro-chemics, but upon Von Helmont rather than on Willis and Mayow; while Hoffman and his school resuscitated the *strictum* and *laxum* syllogisms of the Greek Methodists.

In this sketch of the past, a sketch necessarily indiscriminate, but not, I trust, indiscreet, we have seen that up to the time of Avicenna, medicine was one and undivided; that surgery was regarded truly, not as a department of disease, but as an alternative treatment of any disease which the physician could reach with his hands; that the cleavage of medicine, not by some natural and essential divisions, but by arbitrary paltering to false pride and conceit, let the blood run out of both its moieties; that certain diseases thus cut adrift, being nourished only on the wind, dried into mummy or wasted in an atrophy, and that such was medicine; while the diseases which were on the side of the roots, if they lost something of their upper sap, were fed from below, and that such was surgery.

Thus the physicians who were cut off from the life-giving earth, being filled with husks and dust, became themselves stark and fantastic. Broadly speaking, until the seventeenth century pathology was a factitious schedule, and medicine a farrago of receipts, most of them nauseous, many of them filthy; most of them directly mischievous, all of them indirectly mischievous as tokens of a false conception of therapy. A few domestic simples, such as the laxatives, are indispensable; for the rest we are tempted to surmise that mankind might have been happier and better if Dioscorides had been strangled in his cradle.

This is the truth I have tried to get home to you, that in the truncation of medicine the physician lost not only nor chiefly a potent means of treatment; he lost thereby the inductive method; he lost touch with things; he deprived his brains of the coöperation of the subtlest machine in the world — the human hand, a machine which does far more than manufacture, which returns its benefits on the maker with usury, blessing both him that takes and him that gives.

Pure thought, for its own sake, especially in early life, when the temptation to it is strong and experience small, seems so disinterested, so aloof from temptation of gain, that in the history of ideas, speculation and the construction of speculative systems have played but too great a part, and have occupied but too many minds of eminent capacity. We must assume then that they have served —and for aught we know may still serve — some good end. It seems hardly likely that age after age men would busy themselves to build up these vast constructions in idle exercise. That nature is wasteful we know but too well; yet she is wasteful by the way, not in the main direction of her work. If some of her seed falls on stony ground, if her rain falls on the just and on the unjust, yet the sowing and the rain are in the main fruitful and delightful. Peradventure, in our modern conviction of the efficiency of the inductive method we may be too ready to denounce other methods which, hard as it may be for us to conceive, may yet play some lasting part in evolution. Even in our own day we may become too analytical; on our good side we may be too exclusive. In the pale hue even of inductive analysis may we not get sick, lose resolution in too much deliberation, overlook the concrete, and forget that if by any mode of generalization we lose hold of individuals in types, and of things in the negations and eliminations of abstraction we may fall ourselves into the very error of the "school-authors." If the search for entities was false, may there not be a sort of imposition in "laws"? When in the last analysis we attain to unresolved residua may we not err in giving even to a true residuum too solid a name? Whether it be the summation of phenomena or a vision of the imagination an abstraction is an abstraction, and abstractions carry us a long way from deeds and things.

In the minds of academical teachers the notion still survives that the theoretical or university form and the practical or technical form of a profession or trade may not only be regarded separately, and taught in some distinction, which may be true, but in independence of each other; nay, that the intrusion of the technical quality by materializing, degrades the purity or liberality of the theoretical; that indeed if he had not to get his daily bread the high-minded student may do well to let the shop severely alone. Thus the university is prone to make of education thought without hands; the technical school, hands without thought; each fighting shy of the other. But if in a liberal training the sciences must be taught whereby the crafts are interpreted, economized, and developed, no less do the crafts, by finding ever new problems and tests for the sciences, inseminate and inform the sciences, as in our day physics are fertilized by the fine craft of such men as Helmholtz, Cornu, and Stokes; and biology by that of Virchow, Pasteur, and Lister. At the commemoration of Stokes in Westminster Abbey, Lord Kelvin honored in him the "combination of technical skill with intuition;" and Lord Rayleigh admired in him "the reciprocity of accurate workmanship and instinctive genius;" appreciations no less true of these two distinguished speakers themselves. If it be true, as I have been told, that the University of Birmingham has a coal-mine upon the premises, I am ready to believe that the craft of coal-getting, by carrying practice into thought, will fortify the web of theory.

There exists, no doubt, the contrary danger of reducing education to the narrow ideas and stationary habits of the mere artisan. By stereotyped methods the shop-master who does not see beyond his nose, may cramp the 'prentice, and this 'prentice becomes shop-master in his turn. If in the feudal times, and times like them in this respect, manual craft was despised, and the whole reason of man was driven into the attenuated spray of abstract ingenuity, in other times or parts of society a heavy plod of manual habit so thickened "the nimble spirits in the arteries" that man was little better than a beaver: on the one side matter, gross and blockish; on the other, speculation vacuous of all touch of nature. We need the elevation, the breadth, the imagination which universities create and foster; but in universities we need also bridges in every parish between the provinces of craft and thought. Our purpose must be to obtain the blend of craft and thought, which, on the one hand, delivers us from a creeping empiricism, on the other, from exorbitant ratiocinations. That for the progress and advantage of knowledge the polar activities of sense and thought should find a fair balance, is set forth judicially enough in modern philosophy, and is eminent in great examples of mankind. Moreover, it is apprehended in the reciprocal tensions of faith and works, of hypothesis and experience, of science and craft. In our controversies on theory and practice, on universities and technical schools, on grammar and apprenticeship, we see their opposite stresses. The unison is far from being, as too often we suppose, one merely of wind and helm, it is one rather of wind and wing; it consists not in a mere obedience of hand to mind, but in some mutual implication, or generative conjugation of them. How these two forms of impulse should live in each other, we see in the Fine Arts — in the swift confederacy of hand and mind in Dürer, Michael Angelo, Rembrandt, Velasquez, Watteau, Reynolds. The infinite delicacy of educated senses is almost more incredible than the compass of imagination. When they unite in creation no shadow is too fleeting, no line too exquisite for their common engagement and mutual reinforcement. Michael Angelo and Leonardo da Vinci, the greatest craftsmen perhaps the world has seen, were as skillful to invent a water-engine, to anatomize a plant, or to make a stonecutter's saw, as to build the dome of St. Peter above the clouds of Christendom.

Solve the problem as hereafter we may, now we can take heed at least that energy shall not accumulate about one pole or the other. Our little children have a message to us if we would but hearken to them. Every moment they are translating action into thought and thought into action. Eye, ear, and hand are incessantly on the watch and in pursuit, gathering incessantly for the mind and the forms of thought which as rapidly issue again in new activities. If, as we mature, we gain the power of restraint, it is not that we shall cease to act, that the mind shall depose the hand, but that these variables shall issue in a richer and richer function. If we forget the hands, that cunning loom which wove our minds, if thrusting them into our pockets, we turn our eyes inwards, will our minds still truly grow? That by virtue of the apposable thumb monkey became man is no metaphor; in its measure it is sober truth. For the last millennium too much thinking has been the bane of our profession; we have actually made it a point of honor to ignore the hands out of which we were fashioned, and in this false honor to forget that the end of life is action, and that only by action is action bred. While we profess to admire Bernard Palissy or Jean Goujon, the medieval mason or the medieval goldsmith, we act nevertheless as if fine arts only are honorable, and mechanical arts servile; whereby we blind ourselves to the common laws of growth, which, knowing not these distinctions, deal out barrenness to those who make them. We begin even with our children to wean them from the life of imaginative eyes and of thoughtful fingers; and instead of teaching them to rise from simple crafts to practical crafts, to scientific crafts, or to lovely crafts, and thus to pursue the mean of nature herself, we teach them the insolence that, except in sports, the mind should drop the acquaintance of the fingers.

Shall we wonder then that in this generation bold men call English people stupid; all stupid save those few men of genius or rich talent who, like Gilbert, Harvey, or Darwin, were great enough to be true to eye and hand, and to breed great conceptions by their intimate coition with the mind? Shall we wonder then that medicine fell into sterility when by most unnatural bonds surgery, her scientific arm, was tied behind her, and her sight was turned inwards from processes to formulas? Shall we wonder that even in the eighteenth century, when medicine had begun tardily to occupy itself in the crafts of pathology and chemistry, one visionary after another, striding in long procession athwart the barren wilderness of physic, wasted his generation in squeamish evasion of the things that happen, and in vain pursuit of vacuous unities? Yet, if to the high stomachs of our forefathers surgical dabblings were common and unclean, still there remained some eyes curious enough and some fingers dexterous enough to carry the art back to the skill of Hippocrates, and forward to the skill of Lister; but it was by the mouths of barbers and cutters, rather than of the pharisees of the colleges, that medicine breathed her lowly message to her children.

THE PROBLEMS OF INTERNAL MEDICINE

BY WILLIAM SYDNEY THAYER

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To recognize, to prevent, to protect, to heal — these are, in the broadest sense, the tasks of internal medicine now as ever. But how different are the problems which occupy our attention to-day from those of the period commemorated by this Congress. Let us for a moment glance back at the medicine of the close of the eighteenth and the beginning of the nineteenth centuries. For over two hundred years the blind and binding faith of the Middle Ages, the faith that had so long fettered the human mind, had been slowly giving way before the forces of reason and truth. Now and again with ever increasing frequency, great and courageous minds had risen above the clouds of medical tradition and dogma which had smothered the understanding and reason of mankind, as if, indeed, medicine were a part of the religious doctrine which ruled the world. For truly the medicine of the Middle Ages was largely a matter of faith, and as a matter of faith one in which reason beyond a certain point was heresy and sacrilege. Vesalius with genius and courage had begun to withdraw the veil from naked and iconoclastic truth. Harvey had made his great discovery. Glisson had demonstrated his theory of irritability. Mayow, with his "Spiritus nitroaëreus," had anticipated the discovery of oxygen. Leeuwenhoek and Malpighi and Hooke had opened to the human eye the realm of the infinitely small. Bacon and Descartes and Newton and Locke had introduced into the world a rational and natural philosophy. Locke, himself indeed a wise physician, had pointed clearly to the true path of medical progress. "Were it my business," says he, "to understand physick, would not the safer way be to consult nature herself, in the history of diseases and their cures, than espouse the principles of the dogmatists, methodists, or chymists?"

But the clouds of medical tradition were slow to clear away.

Gradually, however, the first "lonely mountain peaks of mind" were followed by an ever increasing number of earnest and untrammeled students. In the seventeenth century the opportunity to give one's life freely to the search for truth had become more and more open to all. The mysticism and animism of Stahl, which, in the early part of the eighteenth, hung over the medical world, was already breaking away. The study of the natural sciences was pursued more eagerly and generally than ever before. Réaumur and Black and Haller and Spallanzani and Hunter and Priestley and Lavoisier had lived. Morgagni, sweeping aside the dogmatism of the old schools, had demonstrated the local changes in many diseases and had opened the way for the objective pathological anatomy of Bichat. In the field of practical medicine such men as Sydenham and Morton and Torti and Lancisi practiced and taught much which holds good to-day. Boerhaave had introduced clinical instruction. Cullen and Cheyne and Huxham and Pringle and Heberden and Van Swieten and De Haen were all in many ways true and faithful students; yet methods and doctrines that were often strangely fantastic still held general sway — such, for instance, as the Brunonian system. A perusal of the writings of Stoll, one of the wisest practitioners of his day, cannot fail to impress one with the meagerness of the basis of anatomy and physiology, normal and pathological, on which medicine rested, the almost entire lack of diagnostic methods, the absence of a rational therapy — how much of the conjectural, how little of the scientifically exact there was in medicine.

Diagnosis, based largely upon gross clinical conceptions, was necessarily vague and uncertain.

Prophylaxis, in the absence of any certain knowledge of the causes and manner of origin of disease, was devoid of any sound basis.

Treatment was almost wholly empirical, and, where it was not empirical, it was frequently based upon some theoretical system so arbitrary and dogmatic that the unfortunate sufferer was too often stimulated or purged, fed or bled, as he fell into the hands of a Brown or a Broussais, rather than according to the nature of his malady.

In the Dictionnaire de l'Académie française for 1789, a year which marks the end of an era in the world at large, one finds the following definition: "Médecine. *s. f.* L'art qui enseigne les moyens de conserver la santé & de guérir les maladies. (La médecine est un Art conjectural. * *)" Medicine a conjectural art! Such was the estimate placed upon our profession by the French Academy a little over one hundred years ago.

But the seeds of a new life had been sown and the germination had already begun. Even as these words were written Lavoisier, too soon to fall a victim to the premature explosion of the forces of pent-up freedom, was in the midst of his great work. In 1796 came the introduction of vaccination by Jenner, and but a few years later, Bichat with his wonderful genius, took up the thread dropped by Morgagni and placed anatomy and physiology, normal and pathological, on a basis of accurate observation and experiment. Hand in hand with the introduction of exact methods of anatomical and physiological observation, Auenbrugger, in 1761, had demonstrated in his *Inventum Novum,* a method of physical investigation which, for the first time, enabled the physician to determine changes in size, shape, and consistency of the thoracic organs. At first unnoticed by the world, this important discovery was destined to gain a sudden general recognition in the early days of the nineteenth century. With the spread of knowledge of the gross pathological changes in disease which followed the inspiration of Bichat, the work of Auenbrugger, expounded by Corvisart, became a common possession of the medical world, and, less than ten years later, Laënnec, by the introduction of mediate auscultation, opened possibilities for accurate physical diagnosis such as had not been dreamed of in the ages which had gone before.

With the great school of French observers which followed Laënnec, Andral, Chomel, Louis, Bouillaud, and Trousseau, with Skoda and Schönlein in Germany and Addison and Bright and Stokes in England, the exact association of clinical pictures with local anatomical changes made great advances. Typhus and typhoid fevers were distinguished; the relation between albuminuria and renal disease was demonstrated; the association of endocarditis with acute rheumatism was discovered; the corner-stone of our knowledge of cerebral localization was laid. Clinical diagnosis was becoming more than a conjectural art.

In the mean time physiology was making great strides. Majendie, Bell, Johannes Müller, Beaumont and finally Claude Bernard, and a host of their followers, were shedding light upon many obscure corners of our knowledge of the vital functions. In the hands of Müller the microscope began to open up new fields of study which were destined in a few years through the cultivation of the genius of a Virchow and a Max Schultze to bear a noble harvest. The "great reform in medicine" which followed the introduction of the cellular pathology laid solid foundations for much which is most vital in our anatomical and physiological and pathological knowledge of to-day, and the correlation of these observations with the results of accurately recorded clinical studies, the application of the microscope to the study of the urine, the sputa, the blood, to pathological neoplasms, to exudates and transudates, soon brought new material for the rising edifice of a rational, exact diagnosis. The sphygmograph, the thermometer, the ophthalmoscope, the laryngoscope, the binaural stethoscope, the stomach tube, the various means for studying the blood-pressure, all have brought their aid, while but yesterday the discovery of Roentgen has given us new and unhoped for diagnostic assistance.

At the same time physiological chemistry which, with the work of Berzelius on the urine, had taken its place by the side of the more purely physical methods of investigation, has year by year given us greater diagnostic assistance in the analysis of the different secretions and excretions of the body and in the explanation of the various metabolic processes of the economy.

The development in the hands of Duchenne and Erb and Remak of electrical diagnosis, together with the great advances in physiology and pathology of the nervous system, has afforded explanation for much that was previously incomprehensible and has given us powers of diagnosis which a few generations ago would have seemed almost magical.

Finally Pasteur and Koch, with the introduction of bacteriological investigation, opened the way to the discovery of the causal agents of a large group of infectious diseases. These discoveries, followed rapidly by the evolution of methods allowing of the clinical demonstration of many pathogenic microörganisms, afforded an early, exact, and positive diagnosis, on the one hand in conditions where previously the disease was recognizable only at a stage in which it had made inroads into the system so great as to be often beyond relief, as in tuberculosis, and on the other, in maladies, the existence of which without these methods was to be definitely determined only after the onset of an epidemic, as in cholera, plague, and influenza. When one thinks of what the last quarter of a century has taught us with regard to tuberculosis, anthrax, tetanus, diphtheria, typhoid fever, cholera, plague, dysentery, influenza, not to speak of the great group of wound-infections, we may begin to realize what bacteriological methods have done for diagnosis — how many diseases have been cleared up — how many symptoms have been explained.

In like manner Laveran, with the discovery of the parasite of malarial fever, did much to bring certainty and precision into a field in which many had gone astray, while opening the way for the important observations of Theobald Smith and all the knowledge which we have gained in recent years with regard to the hematozoa of man and animals.

As a direct result of the introduction of bacteriological methods, the study of the manner of action of infectious agents and their toxic products upon the animal organism, as well as of the powers of resistance of the economy against infection, has given us, with the discovery of specific agglutinines and precipitines, diagnostic methods of the greatest value, not only for the recognition of various infectious processes, but for the identification of specific sera, affording in particular a test for human blood destined (probably) to prove, when properly applied and interpreted, of great medicolegal value.

This is indeed a gain over our knowledge of one hundred years ago. In how many fields has the conjectural given way to the exact! At the end of the eighteenth century the diagnostic effort of the physician, unaided by instruments of precision or even by the simplest physical methods of auscultation and percussion, was directed toward the detection of gross anatomical changes. To-day with our increased knowledge of anatomical, physiological, and pathological processes, with our growing insight into the chemical and physical features of vital activity, our duty no longer ends in the recognition of physical changes in organs, in the determination of the presence of a specific lesion or infection; it is further our task to search for the earliest evidence of disturbance of function, which may later lead to grosser, more evident change, to separate the physiological from the pathological, to estimate, as far as may be, the power of resistance of the different organs and tissues and fluids of the body to insults of varying nature, to determine the functional capacity of a given organ — its sufficiency or insufficiency. In addition to increasing opportunities in the field of pathological anatomy we find ourselves drawn further into the study of pathological physiology — and knowledge in the field of pathological physiology leads of necessity to power in functional diagnosis.

It must be acknowledged that with regard to many organs the determination of the limits of functional power and the estimation of the degree of impairment in disease are matters most difficult to appreciate, yet with improved methods and persistent research, progress is being made.

We are, after all, but beginning to realize a few of the possibilities before us, but even this is a step in advance which holds out no little promise for the future and offers new and tempting opportunities for study and investigation.

At the end of the eighteenth century but three important, rationally conceived measures of prophylaxis had been practiced — the dietetic measures of protection from scurvy, the older inoculation and Jenner's great contribution of vaccination against smallpox. It was not, indeed, until the development of bacteriology that prophylaxis took its place as a scientifically exact branch of medicine. The recognition of the specific cause of many infectious diseases, the knowledge of the life-history of the pathogenic micro-organisms, the discovery of the portals through which they gain entrance to the animal economy, and the conditions under which infection occurs, have brought to us material powers to prevent and protect. The first great result of this new knowledge was the development of antiseptic surgery and all that it represents. But apart from this we have but to remember what has been gained by a scientifically evolved prophylaxis against tuberculosis and typhoid fever — to reflect upon how far cholera and plague have lost their terrors — to contemplate the brilliant results of the discovery by Ross and the Italian school of the life-history of the malarial parasites as manifested in the anti-malarial campaigns carried on in various regions by Koch, and in Italy by the Society for the Study of Malaria, a noble institution, of which our Latin brothers may well be proud, and lastly to look upon the beneficent and far-reaching influence of the recent work of Reed and Lazear and Carroll and Agramonte with regard to yellow fever, to realize what bacteriological and parasitological studies are doing for preventive medicine.

But beyond this external prophylaxis, the studies of the problems of immunity, beginning with Pasteur's inoculations against anthrax in 1881, have given us, so to speak, an internal prophylaxis, a functional prophylaxis, if one will, in the possibility of producing a greater or less degree of individual immunity, such, for instance, as is now possible in diphtheria, cholera, plague, typhoid fever, and dysentery.

The enforcement of scientifically planned and accurately deduced prophylactic measures has become to-day one of the main duties of the practitioner of medicine. It is as much the task of the physician nowadays to guard over the disposal of the sputa of his tuberculous patient, of the excreta of the sufferer from typhoid fever, or cholera, or dysentery, as it is to attend to the immediate wants of the invalid. How rapidly has the exact replaced the conjectural in this branch of medicine!

But while diagnosis and prophylaxis were being removed from the domain of conjecture to the field of exact observation, and reason, and research, while the possibilities of surgery were rapidly widening through the discovery of anesthesia and the introduction of antiseptic methods, medical treatment, until the last two decades, still remained largely empirical. The development of exact clinical methods of observation and the statistical tabulation of experience for which we are especially indebted to Laënnec and Louis, and their followers, gradually brought about, to be sure, many advances, while a large number of useful therapeutic agents introduced by the newly developed science of pharmacology, and exactly tested by improved methods of physiological study, added greatly to the armamentarium of the physician for the relief of symptoms. The power to combat disease specifically, however, remained much as it was at the beginning of the century. Mercury in syphilis, quinine in malarial fever, were the only specifics known to the medical world — and the action of these was unexplained.

The introduction by George Murray, less than fifteen years ago, of the treatment of myxedema and allied conditions by extracts of the thyroid gland, was a direct application of the results of physiological observation to the treatment of disease. If this gave rise to hopes of the possibility of obtaining like results from roughly obtained extracts of other ductless glands, which have hardly been fulfilled, yet the discovery was the first step toward the rational scientific therapy to which we are beginning to look forward to-day.

But a moment ago I spoke of the importance of the influence of the discovery of the causal agents of the infectious diseases upon the development of exact diagnostic and prophylactic methods. Great and impressive as these have been, yet the studies which have followed as to the manner in which these agents act upon the human organism, and of the powers of resistance which the body exerts against them, the investigation of the problems of immunity have opened out a far wider field. The early studies of Metchnikoff and Buchner and Nuttall were followed with rapidity by the epoch-making work of Behring and Kitasato and Roux with regard to tetanus and diphtheria. The diphtheria and tetanus antitoxins were not chance discoveries of empirically determined virtue, but true specific, therapeutic agents, the results of experiment scientifically planned and carefully prosecuted. Widespread investigations of the various phases of immunity, bacterial and cytotoxic, have given us in a few short years a mass of physiological knowledge, the full import of which is scarcely yet to be comprehended. Few things in modern medicine are more impressive than a survey of the work of the last twelve years done under the inspiration of Ehrlich.

Beside the antitoxins of diphtheria and tetanus and the power of producing a greater or less degree of immunity, as has already been mentioned, by preventive inoculations against cholera, plague, and typhoid fever, we have come to possess a bactericidal serum of a certain value in combating the actual disease, plague, while the favorable influence of Shiga's anti-dysenteric serum seems to be undoubted. There is much reason to hope that the recently promised anti-crotalus serum of Noguchi as well as the anti-cobra serum of Calmette may prove to be real boons to humanity. But it is not alone in the production of specific anti-sera that the therapeutic value of the modern studies of immunity lies. There are signs which justify us in looking forward to the possible discovery of an explanation of the mode of action of substances long empirically used, knowledge the value of which may be readily appreciated.

When we consider these facts it is indeed easy to appreciate to what an extent the exact has driven the conjectural from this last field of medicine. A hundred years ago we were depleting and purging and sweating and bleeding according to theories often strangely lacking in foundation, the prevalence of which depended rather upon the individual force and vigor of the expounder than upon their intrinsic merit. To-day from the study of the pathological physiology of bacterial and cytotoxic intoxications, we are rapidly evolving scientific preventive and curative measures, while searching out the rationale and mode of action of our older therapeutic agents.

But a few days ago, I happened to open a copy of Littré[1] bearing, by a curious chance, the date of 1889, and read "Médecine (mé-de-si-n). 1°. Art qui a pour but la conservation de la santé et la guérison des maladies, et qui repose sur la science des maladies ou pathologie" — an essential modification of the definition of one hundred years before and indicative of the changes of a century.

To meet the manifold problems of to-day, the training of the physician must of necessity be very different from what it was a hundred years ago. The strong reaction which set in in the earlier part of the nineteenth century against philosophical generalization in medicine, the insistence upon a strict objectivity, all the more emphatic because of the prevalence of anatomical methods of research, have held very general sway. Medicine, no longer resting upon a basis of philosophical speculation, stands upon the firmer foundation of the exact natural sciences. Almost from the beginning the student of to-day is taught methods, where a hundred years ago he was taught theories. The enormous expansion of the field which must be covered has led naturally, not only to an ever increasing specialism, but to the fact that the course of study which is regarded as properly fitting the physician for practice is reaching backward farther and farther into the earlier years of his school training. On the other hand, in this country at all events, there is heard a common cry that the academic medical training is extending over into years which should be given to practice; that the expense and duration of a medical education, so-called, will soon be such as to shut out from the profession many a man who might be a useful physician and perhaps a valuable contributor to the world's knowledge. To remedy this it is advised that the prospective student of medicine should be led from the earliest stages of his training through the paths of exact research into the domain of the natural sciences to the greater or less exclusion of the classics — the old-time humanities,

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Dictionnaire de la langue française.

the study of which, useful as it may be from a standpoint of general mental training, is believed by many to be time wasted in the education of the student destined for a scientific career.

But there are not wanting voices which question the wisdom of the full extent of some modern tendencies. May the affectation of too strict an objectivity bred though it may be of a wholesome skepticism, the more general cultivation of the natural sciences to the exclusion of the humanities, the search for facts and facts alone, circumscribe the powers of synthetical reasoning without which the true meaning of many an important problem might pass unnoticed? May they perhaps tend to smother the development of minds capable of grasping large general problems? Do the tendencies of the times justify the epigrammatic observation of a recent French author: "Autrefois on généralisait avec peu de faits et beaucoup d'idées; maintenant on généralise avec beaucoup de faits et peu d'idées"?[1]

That the cultivation of a strict objectivity in research has materially impaired our powers of reason — that the exact methods, which are largely responsible for the enormous advances of the last fifty years in all branches of medicine, have bred a paucity of ideas, I am not inclined to believe, despite the seductive formula of our Gallic colleague. But that when in the period of so-called secondary education it is proposed to *substitute* the study of the natural sciences for a good training in the humanities, there is danger of drying-up some of the sources from which this very scientific expansion has sprung, seems to me by no means impossible. The study of the classics, an acquaintance with the thoughts and the philosophies of past ages, gives to the student a certain breadth of conception, a stability of mind which is difficult to obtain in another way. A familiarity with Greek and Latin literature is an accomplishment which means much to the man who would devote himself to any branch of art or science or history. One may search long among the truly great names in medicine for one whose training has been devoid of this vital link between the far-reaching radicles of the past and what we are pleased to regard as the flowering branches of to-day. Greek and Latin are far from dead languages to the Continental student. They are dead to us because they are taught us as dead. With methods of teaching in our secondary schools equal to those prevailing in England and the Continent, it would be an easy matter in a materially shorter period, to give our boys an infinitely broader education than they now receive. There should be much less complaint of time wasted, much less ground for suggesting the abandonment of the study of branches which are invaluable to any scholarly-minded man.

The assertion that the time spent in the study of the humanities results in the end in the encroachment of the academic training upon a period which should properly be given to one's life-work is, it seems to me, often based on an old idea — founded all too firmly, alas, on methods that yet prevail in many of our medical schools — that with his degree in medicine the student has finished a theoretical education, that he must now spend five or ten years in acquiring experience — at the expense, incidentally, of the public — before he can enter into his active life; that, therefore, unless some other branches of early instruction be sacrificed to courses leading more directly to medicine, so that he may enter upon his strictly professional education at a period considerably earlier than is now the case, the physician of to-morrow will become self-supporting only at a period so late in life as to render a medical career impossible to other than those well supplied with the world's goods. With proper methods of instruction this is a wholly false idea. Under fitting regulation of our system of medical training, with due utilization of the advantages offered by hospitals for clinical observation, the experience necessary to render a man a safe and competent practitioner should not only be offered, but required for a license to practice; and even if the length of the strictly medical curriculum be extended one or two years beyond that which is at present customary, it will not be time lost. If one but look around him he will find, I fancy, that few men who have had such a training wait long before finding opportunities for the utilization of their accomplishments; the public in most instances soon recognizes the man of true experience.

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[1] Eymin, *Médecins et Philosophes*, 8°, Lyon, 1903-4, no 4

But there is yet another side of the question which has hardly been sufficiently emphasized, a side of the question which must come strongly to one's mind when one considers the general education of many of the men who are entering even our better schools of medicine, a point of view which has been especially insisted upon by a recent French observer. A large part of the success and usefulness of the practitioner of medicine depends upon the influence which he exerts upon his patients — upon the confidence which he infuses — upon his power to explain, to persuade, to inspire. It can scarcely be denied that these powers are more easily wielded by the man of general culture and education than by one of uncouth manner and untrained speech however brilliant may be his accomplishments in the field of exact science. I can do no better than quote the words of Professor Lemoine: "C'est qu'en effet l'action morale qu'il peut exercer sur le malade, et qu'il exerce d'autant plus qu'il est supérieur par son intellectualité, est un des principaux éléments de guérison. On guérit par des paroles au moins autant que par des remèdes, mais encore faut-il savoir dire ces paroles et présenter une autorité morale suffisante pour qu'elles entraînent la conviction du malade et remplissent le rôle suggestif qu'on attend d'elles. Ne fut-ce que pour cette raison, je me rangerai parmi ceux qui demandent le maintien d'études classiques très fortes comme préparation à celles de la médecine, car le meilleur moyen de rehausser le prestige du médecin c'est encore de l'élever le plus possible au dessus de ses contemporains." [1]

These words express, it seems to me, a large measure of truth. May it not be that in the tendency to the neglect of the humanities we are taking a false step? May it not be that if, on the other hand, we teach them earlier and better, we shall find in the end that no essential time is lost, while we shall gain for medicine-men not only with minds abler to grasp the larger and broader problems, but with materially fuller powers for carrying on the humbler but no less important duties of the practitioner of medicine?

In that which I have just said I have touched upon the necessity of the requirement of a considerable amount of clinical experience as an essential for the license to practice medicine. To meet the enormously increased demands of the present day, medical education has become, of necessity, much more comprehensive, and must therefore extend over a longer period of time. The methods of research, anatomical, physical, chemical, which the student must master, the instruments of precision with which he must familiarize himself, are almost alarmingly multifarious; and experience in the application of these methods and in the use of these instruments demands increased time. Many of these proceedings, it is true, the physician will rarely be called upon to use personally in practice, for such measures must in great part be carried out by special students or in laboratories provided by the Government. Nevertheless with their significance and value he must be familiar — familiar from personal observation and experience.

But after all there are few diagnostic signs in medicine, and not so many of the improved methods of clinical investigation yield diagnostic results, while to familiarize one's self with methods and instruments of precision is a very different matter from acquiring real experience and skill as a diagnostician or a therapeutist. It is only by gathering together and carefully weighing all possible information that one is enabled to gain a proper appreciation of the situation and to approach a comprehension of many conditions of grave import to the patient. And in forming a sound judgment with regard to these vital questions, that which comes from experience in the close personal observation of the sick is far the most important element. Bedside experience constitutes to-day, as it always has, and always will, the main, essential feature in the training of the physician. But this experience, if it is to bear its full fruit, must be afforded to the student at a time when his mind is still open and receptive and free from preconceived ideas — under conditions such that he may be directed by older trained minds into proper paths of observation and study, for few things may be more fallacious than experience to the prejudiced and the unenlightened.

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[1] Indeed the moral influence which he (the physician) is capable of exercising upon the patient and which he exercises to an ever increasing degree with his intellectual superiority, is one of the most important of therapeutic agents. One heals by words at least as much as by drugs, but one must know how to *say* these words and to exercise a sufficient moral authority, that they may bring conviction to the patient and carry the full weight of suggestion which is intended. Were it but for this reason I shall range myself among those who demand the maintenance of extensive classical studies as preparation for those of medicine, for the best means to uphold the prestige of the physician is still to raise him as far as possible above his contemporaries. *Congrès français de médecine*, VI Session, Paris, 1902, 8°, t. II, p. xli.

That such experience may be freely offered to the student there is a grave necessity for a more general appreciation by institutions of medical training as well as by the powers in control of public and private hospitals and infirmaries, of the mutual advantages to be gained by a cordial coöperation. It must be acknowledged that, in this country at least, despite the cultivation of improved methods of clinical investigation, there still prevails in the mind of the public the perverted idea that this bedside observation, this application of new methods of research and study are for the advantage of the student or in the interest of general science rather than for the benefit of the sufferer himself. It must further be recognized that a wholly mistaken conception of the true function of a hospital is widely prevalent. It is all too common to see large and ornate institutions with every arrangement for the comfort and even luxury of the patient, with a medical staff utterly insufficient in number or training to study properly the individual case, not to speak of carrying on scientific investigations. The service, usually under the direction of a busy driven practitioner with barely time to make a short daily visit — large wards under the direct control of one or two young men whose time is wholly occupied by routine work — every care taken for the present comfort of the patient — little provision for enlightened study or treatment of his malady — no opportunities for a contribution on the part of the institution to the scientific progress of the day. Better far for the sufferer were he in the dingy ward of an old European hospital where he might be surrounded by active, inquiring minds recording the slightest changes in his symptoms, ever ready to detect, and as far as the power in them lies, to correct the earliest evidences of perversion of function. What our hospitals need is men, students, whether or no they have arrived at the stage in their career — which, after all, is but a landmark, not a turning-point — that entitles them to the right of independent practice, the enthusiastic, devoted student who, in watching and studying the patient, is contributing alike to the interests of the sufferer, the hospital, and himself.

The three main functions of a hospital — the care of the sick, the education of the physician, the advancement of science — are not to be met alone by building laboratories and operating-rooms and lecture-halls, by furnishing the refinements of luxury to the patient, useful adjuvants though these may be. What the hospital mainly needs is men, men to study and think and work — *students of medicine.*

It cannot be denied that in this respect we in America are behind our cousins of the Old World. Despite our many honorable achievements, the part which we are taking in the modern study of the physiology of disease is still not what it should be.

Ere long we must come to realize that our duty to the sick man consists in something more than to afford him that which most sick animals find for themselves — a comfortable corner in which he may rest and hide from the world; that our duty to the public is to give them as physicians, men of the widest possible general training, ready to enter upon independent practice with an experience sufficient to render them safe public advisers; that our duty to ourselves is to miss no opportunity for the study of pathological physiology at the bedside of the patient; that the accomplishment of these ends depends in great part upon the appreciation by our universities and hospitals of the mutual advantages of coöperation in affording every opportunity for the scientific study of disease while offering to the patient the privileges of enlightened observation and care.

But there are everywhere signs of a future rich in achievement. An improving system of medical education, the increasing opportunities for scientific research offered as well by the generosity of private citizens as by the wisdom of state and national governments, the community of effort which results from closer fellowship among students of all nations, are omens of great promise. The remarkable developments of the last twenty years in all branches of the natural sciences have brought a rich store of suggestion and resource for application in our laboratory, which is at the bedside of the patient. Let us look to it that our clinical methods keep pace with those which are yielding so abundant a harvest in these neighboring fields of scientific research.

SECTION F — NEUROLOGY

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(*Hall* 13, *September* 22, 3 *p. m.*)

CHAIRMAN: PROFESSOR LLEWELLYN F. BARKER, University of Chicago.
SPEAKER: PROFESSOR JAMES J. PUTNAM, Harvard University.

THE VALUE OF THE PHYSIOLOGICAL PRINCIPLE IN THE STUDY OF NEUROLOGY

BY JAMES JACKSON PUTNAM

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THE subject of this address will be considered under three heads: 1. The limitation in usefulness of those methods of medical investigation which are based on the assumption that disease is always a localized process. 2. The importance of the part played in disease by readjustment and adaptation on the part of the organism, and the need of cultivating physiological conceptions as a means toward a proper understanding of these processes. 3. The impropriety of attempting to draw fundamental distinctions between "functional" and "organic" disorders, and the significance of the hypothesis of "energies" as applied to living organisms and to disease.

When the late Professor Virchow was chosen to deliver the opening address before the International Congress at Rome, in 1894, he selected for his topic "The Anatomical Principle in the Study of Disease" (*Morgagni und der Anatomische Gedanke*"),[1] a doctrine to the maintenance of which a great portion of his own long and splendid labors had been devoted. The anatomical principle was not conceived by Virchow in any narrow spirit. Its tenets were that disease is always a localized process, and ought to be susceptible of expression in some sort of anatomical terms, but he asserted that the search for this process might be made as properly through the clinical examination of the patient by the trained physician, together with a careful study of his history, as through the scalpel and microscope of the anatomist. He admitted that the time was still far distant when we should be able to discover the whole of the anatomical evidence, and urged that the inquiry should be extended from the organs to the tissues, and from the tissues to the cells, and even to the very "vital functions" themselves. But he insisted, nevertheless, that in some sense — a sense not as yet strictly defined or definable — every disease was to be thought of as occupying circumscribed areas, in the midst of tissues for the most part or in great part sound. "*Ubi est morbus?*" — "Where is the diseased spot to be found?" — was proclaimed as the watchword of the investigator, while at the same time the students of therapeutics were congratulated on having found means, as a result of anatomic discoveries, to carry local treatment to portions of the body hitherto regarded as out of reach.

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[1] *Berl. kl. Woch*, 1894.

It is needless to attempt a recital of the successes which have been won under this banner of anatomical research. The principle which the great master Virchow proclaimed was one that had appealed and still appeals alike to the faithful plodder and to the man of genius; its history is the best part of the history of medicine during the past half-century; it has been the best thread of guidance since the history of medicine began.

The value of the anatomical principle has been quite as evident for the department of neural pathology as for any other, and the devotion to its maintenance quite as strongly marked. At the meetings of neurological societies the pathologic anatomists have always been more certain of an attentive hearing than investigators of any other sort; in the direction of their work has seemed to lie the sure and trusted path of progress toward a better understanding and a better treatment of disease.

And yet, in spite of all that has been accomplished, there are abundant reasons for the opinion that the very successes of the anatomical principle have thrown unduly into the shade the claims of another mode of approaching the problem of disease, without the aid of which anatomical research must prove inadequate to the task which has been imposed upon it. For this latter principle, which emphasizes the importance of recognition, in disease, the signs of more or less widespread modifications of function of the organism as a whole, the designation of "physiological principle" is appropriate.[1]

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[1] There has been a growing tendency to recognize the importance of this standpoint, and very recently Professor Wolkow, of St. Petersburg, has devoted an able and thoughtful essay to a series of considerations analogous to those here offered. *Die Physiologische Anschauung in der Klinischen Medicin, Berliner kl. Woch*, 1904, nos. 15 and 16.

The argument is not that the anatomical principle is faulty because it has failed to accomplish all that had been hoped of it as regards the discovery of the essential nature of disease, but that, under it, certain local aspects of the disease-process are made the exclusive subjects of research, and that the mind is thus turned aside from a recognition of the fact that an equally important object of study is the modification of functional activity, local or general, which marks the efforts of readjustment on the part of the organism to the effects of the primary disturbance. Such a study as this cannot be adequately made without a thorough use of physiological methods, or of clinical methods inspired and guided by physiological conceptions, the term physiological being understood as including all means of research which throw light upon the mechanism of the processes of life. Psychological and chemical investigations belong preëminently in this category. The faintheartedness which most of us have felt in searching for an anatomical explanation of the great neuroses and psychoses has not been simply a quailing at difficulties which were theoretically surmountable, but has been due in part to a justifiable suspicion that we were not altogether on the right track. We have striven to ticket each one of the histories in our case-books with an anatomical designation indicative of some localized pathological process, but we have realized when we did so that our designations usually fell far short of expressing the whole state of the sick man whom we had before us when the history was made.

The widespread feeling that no investigation of symptoms, however thorough, could give us the sort of insight which we needed has led us to underestimate the real value of such inquiries. If the study of symptoms does not carry us to the heart of the disease, neither does the anatomical study of the disease carry us to the heart of the symptoms. In fact, a thorough inventory of symptoms, that is, an inventory of the signs of disordered functions of the body as a whole, can often tell us more of what we wish to know than an inventory of anatomical signs of altered structure. No anatomical research can pierce to the secret of broken coördinations, and yet it is in these that a great part of disease begins, or comes eventually to consist. No anatomical research can help us to estimate the margin of resistance against strain, and yet on the estimation of this margin, for each individual patient, issues depend which are of scientific and practical importance. One man's health is very different in quality and quantity from another man's health, though the two men, untested, may appear alike, and the investigation into their respective powers of effectiveness and of resistance is often a valuable part of the study of their diseases.[1]

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[1] Physiologists recognize that organs, such as the heart (*cf.* the address by

We need, in short, to supplement our researches into the direct and local effects of a given lesion by a study into the more or less widespread modifications of energy which the organism exhibits as a result of the lesion, and which it is customary to designate as indicative of an attempt[1] to repair the damages which the lesion has induced. We need also to learn a great deal more about the genesis of symptoms, even though we must remain ignorant about the genesis of what one would call disease, in an anatomic sense.

The signs of readjustment constitute, in fact, all that we can really learn in the study of disease, for the disease-process, considered independently of them, is an abstraction, without real existence.

And if this is so, then all the indications of this process of readjustment are proper objects of our study, whether they be of the nature of symptoms or of anatomic marks, whether they concern special localities and organs which are the seat of primary "lesions," or other parts standing in functional relationship to them, and even though they point to changes which are not to be classed as morbid, but rather as modifications favorable to health. The reactions after a so-called "healthy" fatigue, which often lead to new and better powers of endurance, would be of this latter sort, and the same is true of those reactions through which immunity is secured after infectious disease. At such points as these, "disease" and "health" touch hands, and it becomes, indeed, evident that neither disease nor health is a definite condition, but that both of them are movements toward some relatively endurable equilibrium,[2] a goal which is never fully reached.

Of course, to a certain extent, investigations of this sort are daily made by every student, but the question is: In what direction is it now most important that the emphasis of research should be thrown and scientific instincts developed? Imitation and fashion play a large part, even in scientific investigation, and the almost universal tendency to bend all energies to the search for the physical evidence of localized lesions has led too often to a disregard of disturbances usually classified as functional. Not only is it essential that "clinical medicine" should be studied in the light of "physiology," but the field of morbid psychology, which now lies untilled save by a few students, is one of the utmost practical importance for each practitioner.

Welch, cited below) are able, under special stimulation, to work with more than usual effectiveness. This extra force is called "physiologic reserve."

[1] The word "attempt" and others of like meaning are here used not in a teleologic, but only in a descriptive sense, for it seems plain that we must follow the example of the biologists who have studied the problems of growth and of repair (compare Thomas Hunt Morgan, "Regeneration") and admit that there is no justification for assuming a special *vis medicatrix naturae*.

[2] "Stationary Equilibrium." (Ostwald, *Die Philosophie der Natur*.)

We can hardly treat a patient, no matter with what he may be suffering, without having to reckon on the vast and complex part which his mental attitude will play in controlling the result. In many instances, indeed, the physician's success depends upon the skill with which he makes this estimate. Yet how rarely is it systematically and consciously made, under the guidance of any definite principle, and how gladly would most physicians crowd out of sight the necessity for making it at all. A man meets with an injury attended with great nervous shock, and the neurologist is ready enough to spend infinite pains on the study of the necrotic areas in his spinal cord, but is apt to overlook the fact that this localized process does not explain why he has at the same time lost flesh and strength and color, and has become the football of his delusions and his fears. The data gathered by psychologists and physiologists, and the principles based thereon, count for but little in most assemblages of neurologists. The reason usually given for this disregard of psychological and physiological data is the insufficiency of our means for the verification and interpretation of them. But this fear should not hold us back from making the attempt to utilize these facts, for the same uncertainties attend anatomic research the moment we endeavor to use it for probing the essential problems of disease and life. The confusion attending the recent discussions over the neuron theory and the real seat of neural energy both justify and illustrate this statement.

This attitude toward the problem of disease, which claims pathology as a special department of physiology, is essentially the attitude of Wolkow, to whose stimulating essay I have alluded already, and it is also the attitude of Dr. Hughlings Jackson, of London, whose brilliant studies, stretching back for nearly half a century, mark him as foremost among the advocates of the physiological method in neurological research. Professor Welch,[1] of Johns Hopkins University, has recently made substantially the same claim in his address upon "Adaptation in Pathologic Processes," drawing his illustrations from the department of general pathology. Verworn[2] takes the same position when he speaks of diseases as stimuli (*Reize*), which alter the conditions under which life is carried on, thereby adopting Virchow's designation: "*Die Krankheit ist das Leben unter veränderten Zuständen.*"

The physical changes which the organism undergoes in this process of adaptation may be few and slight, and mainly local, or they may be so broad and numerous as wholly to overshadow the lesions by which they were set in motion. In illustration of this overshadowing of the direct effects of a lesion by the processes of readjustment, I will mention three instances of widely different sorts, yet similar, as I think, in principle. These are: First, myxedema; next, the vast changes that sweep through the organism at the great climacteric epochs of adolescence and the menopause; and finally, those kindred processes of metamorphosis by which through castration the bull is converted into the ox.

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[1] *Transactions* of the Congress of American Physicians and Surgeons, 1897.

[2] *Berl. kl. Woch*, 1901, no. 5, and other papers.

In all these cases we see two tendencies at work, the one suggesting disease, or failure, the other pointing toward the establishment of a new sort of equilibrium, containing well-marked elements of stability and health. Is not the controlling principle in these instances analogous to that under which the neuter bee is converted into the queen bee through a change in nourishment, or that through which some of the lower forms of marine animals are altered in type by gradual removal from salt into fresh water, or by some kindred modification of the chemical constituents of the fluids by which they are surrounded?

The conservative physician is usually disinclined to admit biological principles as applicable to the problem of disease. Yet, in fact, it is just in this direction that our search should tend, and when we see complex disorders, such as Graves's disease, or even certain types of neurasthenia, of unknown primary lesion but with hosts of secondary physical and neural signs, we should remember the processes I have cited, and should hesitate before stamping summarily as "disease" modifications of structure and function which doubtless represent, in part, movements toward a new and relatively stable existence. Who can doubt that we ourselves, regarded from another point of view than our own, are defective and mutilated beings, who have sacrificed much to gain the faculties which we justly regard as so important?

This would be a proper place to mention in detail, at least by way of illustration, some of the more important contributions made by physiologists, psychologists, and biologists, which have thrown light upon the clinical problems of compensation and adaptation.

I have already referred to the principle of "physiological reserve" force, as utilized by Welch in his important address, and speak of it here again only as possibly helping to explain the numerous instances where the organism shows the power of fostering certain of the functions of the nervous system at the expense of other manifestations of its life. The case of the runner from the field of Marathon, who brought his message to Athens in spite of the gathering dissolution which laid him dead in the market-place at the moment of his arrival, is a striking illustration of a principle which is of frequent application.

Thus, the disarrangements of the nervous system that are liable to follow nervous shocks of some severity are sometimes very late in making their appearance, and in the interval the patient may appear as if unaffected by the experience through which he has just passed. The final "breaking-down," due to prolonged strain, is often similarly postponed, only to come on eventually with great suddenness.

The fact is often overlooked that there is an analogous "latent period" in the early stages of toxic affections, when the symptoms are masked by this strong tendency on the part of the organism to continue offering an unchanged front in response to the calls of the environment. Thus a patient who is exposed to lead or alcohol may retain the power to use his weakened nerves and muscles for a long period, until finally, under some slight additional strain, complete disability suddenly makes its appearance.

It is apparently this same intense instinct to present a functionally adequate front to the demands of the environment that enables the hysterical patient whose vision is failing to retain the accuracy of the central field, and guides the brain in the reassertion of its powers after injury. The compensation in many cases is so complete as to leave no trace of the primary loss, although some relatively slight additional lesion may make it clearly evident. This is illustrated by the interesting compensatory relationship between the sensory motor functions of the cerebral cortex and those of the semicircular canals discovered a number of years ago by Ewald.

It is as difficult to explain adequately why it is that the organism thus seeks to reassert itself on the old lines, in a physiological sense, as it is to tell why the lower animals are able to make good the loss of important parts and organs, even those of the interior of the body, with regard to which the "habit" of restoration cannot have been acquired through evolution.

Many partial explanations, such as those indicated by Loeb under the name of "tropisms," are indeed of value, but Morgan,[1] after reviewing with great care the evidence at hand for the case of the restoration of the lost parts, declares that a satisfactory explanation is there impossible. One important reason for arriving at this conclusion is that it is by no means invariably true that in the process of restoration the interests of the organism as a whole are consulted. In repair, as in development, the results are often (from the standpoint of the ordinary observer) monstrous or grotesque. And so, too, in human pathology, the processes of compensation and readjustment seem sometimes to work distinctly toward disease instead of health. Nevertheless, these processes must remain the main subject of our study, and the principles underlying them must be re-stated more and more broadly in physiological and philosophical terms, before a unifying conception can be reached.

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[1] *Regeneration.*

It is to the clear insight of Hughlings Jackson[1] that we owe some of the most fruitful suggestions as to the mode in which symptoms of disease arise when the normal balance between the various functions of the nervous system has been broken. New light has been thrown on many of the phenomena of which he speaks by the physiologists who have worked on the vast subject of inhibition, and the effects of a disturbance of the interplay between inhibition and excitation. The names of Meltzer,[2] Sherrington, Biedermann, and Wedenski[3] come to mind, especially, in this connection. Nevertheless, the fundamental principles which Hughlings Jackson so long ago expressed retain for the most part their validity. He made it clear that the signs and symptoms met in disease are of dual origin, that portion of them which is due to a lesion such as we might expect to demonstrate anatomically being often the less conspicuous part, while the more conspicuous part is due to the vital energy of the uninjured remainder of the nervous system, acting without due control and yet with reference to such coördination as is still in force. Special and reciprocal coördination of this sort exist between the cerebellum and the cerebrum, so that the special tensions and characteristics of either one is liable to come singly or preëminently into play when the activity of the other suffers a check. The disorders thus set up form "complementary inverses" of each other. Similarly, when any portion of the nervous system is damaged, there are signs of defect, or "negative symptoms," due to impairment of the more highly coördinated functions of the part concerned and related parts, and signs of overaction, or "positive symptoms," due to uncompensated activity of the functions of "lower levels."

These "positive symptoms" might be classified simply as if due to unchecked liberation of energy, or as attempts at compensation (in a duly qualified sense) on the part of the organism as a whole. Sometimes the phenomena which seem at first glance to bear the stamp of "disease" are really better classifiable as of conservative or compensatory nature, while under other circumstances the reverse may also be the truer statement. Thus Strohmeyer[4] has pointed out how "compulsive ideas" may sometimes have a value for the mental health of the patient, and Hughlings Jackson has suggested an explanation for the fact that motor convulsions, in epilepsy, may, at least, be less injurious for the mental condition of the patient than the seemingly less serious psychic seizures.

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[1] The first lecture of "Hughlings Jackson Course," delivered in January, 1898, contains a brief outline of the importance of his generalizations. (*Lancet*, January 8, 1898.)

[2] *Med. Rec.*, June 7, 1902. "The Rôle of Inhibition in the Normal and Some of the Pathological Phenomena of Life. and Other Papers."

[3] Pfluger's *Arch. f. d. ges. Physiol.*, 1900.

[4] "The Conception of Compulsive Ideas as a Safeguard Neurosis" ("Abwehrneurosen"), *Cbl. f. Nervenheilkunde u. Psych.*, vol. XIV, 1903.

We owe also to Hughlings Jackson the generalization that lesions which occur suddenly, and throw out of gear, as they are bound to do, the more delicate of the functions represented in that part of the nervous system which is concerned, are likely to be followed by symptoms of a more violent sort than those which take place slowly. Thus, the epileptic discharge accompanying a lesion so slight as to leave no recognizable anatomic trace behind is liable, by virtue of its suddenness, to give rise to a maniacal outbreak, which represents the uncontrolled activity of relatively uninjured portions of the brain, while, on the other hand, lesion which anatomically may appear infinitely more serious are accompanied by no such outburst. Different forms of epileptic discharge and their secondary results differ widely also among themselves in these respects.

These hypotheses are in need of further analysis and should be tested anew by neurologists trained in physiological methods.

Reasoning on lines similar to those laid down by Hughlings Jackson, Edward Cowles has recently sought to unify the various members of the large class of the psychoneuroses of exhaustion, or of lowered mental tension. Thus the different phases of manic-depressive insanity are not due, he thinks, to separate and specific processes for which we might expect to find special chemic or anatomic expressions, one process leading to excitement and another to depression, but these phases, which in fact are often mixed, are phenomena of secondary occurrence, and are explicable on principles analogous to those outlined above as indicating the genesis of epileptic mania.

Some of the principles brought out by Hughlings Jackson are quite in harmony with those insisted upon of late years by a relatively small group of observers, abroad and at home, who have brought psychologic investigations to the aid of clinical research. I have especially in mind the fine work done by such men as Janet and Freud in Europe, Morton Prince and Sidis in America, not to speak of many others who have labored in the same field. To them we owe such knowledge as we now possess of the contrast between the dissociation of consciousness so characteristic of hysteria, and of the contrast between this tendency and that which gives rise to the complex and varied mental phenomena of asthenic states, or to the temporary and quasi-normal disturbances of daily life.

It would be impossible even to name, in a few paragraphs, the many clinical researches tending toward a better understanding of mental symptoms, for the prosecution of which a knowledge of psychological and physiological generalizations is essential. A few illustrations must suffice.

Thus, in every movement leading to exact thought and exact expression, in every movement of the memory, vast numbers of mental processes must coöperate, and if the outcome is to be effective, this coöperation must be governed from the outset by a leading idea as a ruling motive. The failure of this ruling idea leads to the wayward flight of thoughts, so characteristic of various forms of mental weakness, as has been pointed out by Liepmann.[1] The psychological bearing of this principle has repeatedly been insisted on by the keen psychologist, Bergson, both in his work on memory and matter,[2] and in a more recent essay.[3]

The psychological researches into *habit* and *set* are likewise of practical importance. The laws of habit describe the tendencies under which the varied reactions of the nervous system recur under forms which are really stereotyped and predetermined, although simulating the purposive reaction of health, and often only with difficulty to be distinguished from them. The term "set" describes the process by which the reactions of every individual, beside their purposive significance, receive a form and coloring, which, in a measure, reflect the general characteristics of the personal life of the actor, his temperament, his racial traditions, his education. It indicates, as has been justly said, the "signature" in the musical sense, under which the movement of his life goes on. The "set" of each patient must be understood before his illnesses can be mastered. In the study of these important laws psychologists and neurologists can lend each other mutual support.

If a further illustration was needed of the way in which a refined study of physiology and psychology can be made of the highest use to supplement anatomic data, in affording a basis for clinical conclusions, it could be amply furnished by a consideration of the problems of fatigue, that mysterious region, daily traversed, where health and sickness are so strangely mingled.

Thanks to recent investigations, we know a good deal about the anatomy, chemistry,[4] and physiology,[5] of the nervous system in fatigue, as representing the primary lesions, but it needs only a brief reflection to show how numerous and varied are the secondary manifestations, neural and mental, involving eminently the functions of the organism as a whole and in all its parts, that characterize the clinical outcome of acute or of prolonged exhaustion.[6] To give to these manifestations an adequate expression would often mean the passing in survey the functions of all the organs of the body. This is a task which would be anatomically impossible, since even the most extensive anatomical survey would fail to take cognizance of the disarrangements of old coördinations and the establishment of new ones.

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[1] *Ueber Ideenflucht*, publ. by Carl Marhold, Halle, 1904.

[2] *Matière et mémoire.*

[3] *L'effort intellectuel, Rev. Philosophique*, 1902, p. 53.

[4] See especially various papers by Verworn and his pupils, which are published or referred to in the recent volumes of the *Zeitschrift f. Allgem. Physiologie*, 1901 to 1904.

[5] See especially Richet, *Dictionnaire de Physiologie*, article "Fatigue."

[6] See "Neurasthenia," by Cowles, Shattuck Lecture, 1891, *Boston Med. and Surg. Jour.*; see, also, the various accounts of the Exhaustion Psychoses, and of studies on the contests in the Olympian games.

Almost equally important with the generalization that the manifestations of disease are largely compensatory or adaptive, *i. e.*, vital or physiological manifestations on the part of the organism, is that which describes these changes as affecting *not organs, but functions.* This view is justly made much of by Wolkow, who points out that too close an adherence to the analytic methods of the anatomist encourages a tendency to regard the body as a congeries of organs, of tissues, and of cells, having an independence of each other which, in reality, they do not possess. A mode of conception such as this robs the organism, regarded as a whole, of its individuality, and as a substitute for it we need to cultivate the habit of regarding each individual as representing a vast system of interlocking functions, partly known to us already, partly unknown. It is during the disturbances and reorganizations of these functions, either in themselves or in their relations to each other, that the symptoms of disease arise, and the problem of the physician is to cast up the patient's account at each critical juncture, and to reckon upon what assets, in a physiological sense, he has yet to reckon, upon what powers of compensation and readjustment he can still rely. In place of regarding the body so much by piecemeal, we need to regard it more as a whole; as a supplement to our study of structure we need a closer study of function. Some diseases, as Wolkow suggests, could best be defined as disorders of unknown functions. It is probable that, under the same principle, those disorders which we now classify as due to premature death of anatomical parts[1] could be more properly described as due to the premature falling-out of more or less specialized functions.

In no department of pathology is it so difficult to arrive at satisfactory conclusions by the aid of the anatomic method alone as in the department of neural pathology. For it is the nervous system upon which the organism preëminently depends for the very existence and efficiency of these interlocking functions which are the basis of life. We can get on without admitting the existence of matter, in the familiar sense of that word, but we cannot get on without admitting the existence of *energies*,[2] superposed one over

[1] Termed by Gowers "abiotrophy."

[2] Of course, in the final analysis, it must be admitted that any given conception of "energies" can be taken only in a symbolic sense. It is, however, at present, the term most conducive to clear thought and adequate generalization.

another in ever increasing complexity of organization, and to admit this conception of energies is at once to throw the emphasis of research upon the study of functions, and to admit the significance of the anatomical method only as a valued help toward the better understanding of function.

One unfortunate result of a too close adherence to the anatomical method is that it has introduced into medical literature, and, more important still, into medical thought, a differentiation of disease into two contrasted, although vaguely defined, categories designated as "functional" and "organic," two terms which are objectionable because they help to perpetuate false notions of physiologic, pathologic, and clinical sorts.[1]

However useful these terms may have seemed as affording a convenient, if rough, classification of diseases, and however inspiring it is to reflect that with the idea of "functional" goes that of possible curability, it is nevertheless true that their employment has had a mischievous because misleading effect, and that it turns away the mind from the true recognition of a nature of the facts at stake.

Contrast, for example, the cases of hysteria and epilepsy, with regard to which these terms are often used, as if with an essential meaning. If in calling hysteria "functional" and epilepsy "organic" it is meant that the one is curable and the other incurable, neither assumption is strictly accurate. If it is meant that in the case of hysteria there is, presumably, no essential anatomic peculiarity of the brain and nervous system, while in epilepsy such a peculiarity is present, neither assumption is correct. For no one can doubt that the brain of the hysteric is in some degree abnormal, and while we must make the same assumption in the case of epilepsy, we know nothing of the actual change which brings the epileptic fit about or makes it possible, nor can we even say that the fit itself is not a conservative process, in a certain sense. Again, the epileptic paroxysm, as such, is a sign which distinctly deserves the name of "functional," as much when occurring spontaneously as when induced by experimental excitation of the cortex. Furthermore, it would be only partially correct, and certainly not scientific, to call hysteria a "functional" and epilepsy an "organic" disease because epilepsy occurs oftener than hysteria in patients who exhibit certain physical peculiarities which we classify as stigmas of degeneration.

It would be equally erroneous to claim that having classified a disorder as "hysterical," and therefore as "functional," we have the right to consider it as representing a condition which anatomy need not take into account. Mental action is, in every sense, a real force, standing on the same plane with the other forces which we regard as more familiar, and as such it is capable of influencing the nutrition of the body. It is only by evasions and subterfuges that we can deny the reciprocal relationship between bodily processes and mental states. Both of them are manifestations of energy, and there must be some denominator common to them both. Between death from a bullet that traverses the brain and death from an emotional shock, the difference is one solely of detail. When any disorder such as we should be inclined to call functional is hostile to the fundamental interests of the organism, it leads at once to manifest disorders of the nutrition. Not only is this true of depressive emotions, but even of excessive intellectual preoccupations, as when Dante said, "My great work has made me lean." This datum of common observation is receiving, more and more, the solid indorsement of scientific thought. Thus, Ostwald [1] dwells upon the fact that mental operations of a pleasurable sort directly favor nutrition and the normal flow of chemical energy, while those of a painful sort interfere with nutrition and hinder the flow of chemical energy.

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[1] Compare in this connection Obersteiner, *Functionelle und Organische Erkrankungen*, 1900; and Krehl, *Die Functionelle Erkrankungen*, in *Die Therapie der Gegenwart*, 1902.

At both these latter points the barrier between the functional and the organic is broken down. As a matter of fact, this barrier does not by right exist, and we should not be tempted to use the terms "functional" and "organic" as applied to disease at all were it not for two reasons, the first being the convenience of the custom, the second that there are many conditions which we recognize as being on the whole hostile to most of the interest of the organism and which we therefore feel justified in classifying as disease, yet where the disorder is not adapted for anatomical expression. If we adopted, as we should, the conception defended by the clear-minded philosopher and scientist (Ostwald), that the organism is a fabric built up, not of atoms, but of energies, we should never draw these unscientific distinctions between "function" and "structure," or "symptomatology" and "anatomical expression," as standing for fundamentally different and contradictory conceptions, or as affording the one a truer and the other a less true method of approaching the study of disease, but we should admit that the data gathered under these different headings stand upon the same plane as regards their admissibility as evidence. The data furnished by the study of symptoms, which in the case of the so-called functional disorders constitute all the evidence at our command, are data of a physiologic sort, and throw light rather on the reactions of the organisms than on the direct effects of the primary lesion. For this reason they are not susceptible to discovery by anatomic means.

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[1] *Philosophie der Natur.*

In conclusion, then, I offer the following propositions:

Every organism, whether we call it diseased or well, presents itself to our view as a web of interwoven "energies," which, in order to study them by anatomic means, we must break artificially into fragments that have, in reality, no correspondingly separate existence.

These energies, under tendencies which countless ages of evolution have established, have woven themselves into a mechanism of interlocking functions, forming an endurable and relatively stable equilibrium, which we denominate as health. This equilibrium, however, must always remain but relative, and would become a real equilibrium if that were possible only at the sacrifice of further evolution and progress.

The processes of mutual modification and adjustment through which such an organism seeks to gain and to maintain this equilibrium, under the ordinary conditions which we classify as health, are the only means which it possesses to meet the more serious needs created by the unusual conditions that we call disease.

It rarely happens that these efforts [1] at readjustment (after any considerable disturbance of this equilibrium) are thoroughly successful, and in the abortive or exaggerated reactions on the part of the organisms, energies are set free and habits are established which are often hostile to the main interests of the organism as a whole, and therefore are reckoned as evidences of disease.

In many cases the processes of readjustment are taken part in by various functions of the organism which do not seem to be at first sight related to the changes primarily at stake, to such an extent that the earlier effects of the original lesion are overshadowed, and we seem to be in the presence of what would be called a change of type rather than a disease. In this way, for example, what are called by biologists the "secondary sexual characters" arise. Clinical examples of this tendency toward such a generalization of the process of readjustment have already been suggested.

Although these processes of readjustment do not seem to be guided by teleologic influences, and although they often fail to benefit the organism, and, instead, work it great mischief, yet in many instances they do have all the outward appearance of being under the direction of some general principle analogous to that which governs the processes of growth, and is manifested in the repair of lost parts among the simpler forms of life.

The tendency, according to which the processes of repair are governed by a "general principle," presents interesting analogies with the government of the flow of thought and memory by a "leading idea." The same tendency probably finds application in fact, in the case of all complex reflexes, no matter of what sort.

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[1] It is to be understood, as stated above, that the term "efforts" is here used in a descriptive sense alone.

In order to give aid and guidance to the more favorable elements of these processes of readjustment, we, as physicians, need to bend all our powers to a better understanding of the resources which each organism has at its command for compensation, for continued life on the old lines, or for gaining a new and more stable life, no matter at what sacrifice. The patient who thoroughly understands his resources and is master of them, even if these are few and slight, is often in a better position than one who has more to draw upon but who is liable to be upset by surprises.

In the accomplishment of this task we need all the help that anatomy can furnish, but as it is the organism in activity that we seek eventually to understand, it is necessary that the splendid services of anatomy should be supplemented by physiology, and the physician — above all the neurologist — needs, therefore, to be trained, more thoroughly than at present, to work and reason in accordance with physiological conceptions and methods as applied to the problem of disease.

As regards our duty in the treatment of our patients, we should not fail, first of all, to seek for the original cause, wherever it may lie by which the old equilibrium of relative health has been, in one direction or another, broken into, and we are, therefore, bound to acquaint ourselves with all those functions and processes which are related to nutrition in the broadest sense. Still, for the neurologist in particular, the problem of nearest interest is often to gain a point of temporary vantage for his patient by training him to make the best of a present situation, and the methods by which this end is to be accomplished are classifiable under the general name of education.

In these methods the future therapeutics of the nervous system is largely to assist; to them we are more and more to look for guidance, both in relieving our patients of their ills and in teaching them how to bear them. The physician who knows best how to appreciate the needs and resources of those coming under his care, to divine their capabilities, to search out the hidden causes of their present troubles — lying, perhaps, in the experiences of childhood — the physician who has the trained keenness to recognize that, however poor the material with which he has to work, there is almost invariably some benefit to be gained, if not in the direction of relief, then in that of compensation — such a physician as this can make himself of infinite service to the community in which he lives and works.

As among the newer representatives of the successful laborers in this field, we ought to recognize not the scientific investigators alone, but also those practical workers, whether lay or medical, who have shown what education can actually accomplish. I have in mind, especially, the physicians who have demonstrated that tabetic ataxia can be relieved, the sufferers from obsessions and morbid fears restored to their place in society, the vacant lives of imbeciles and dements made more full, and new promise given to the efforts for the reform of the waifs and wards of our great cities. In this outcome is to be sought one of the best practical pieces of evidence for the value of the physiological principle in the problem of disease.

SHORT PAPER

Dr. C. L. Herrick, of Granville, Ohio, contributed a paper, read by his brother, Dr. C. Judson Herrick, on "A Comparative Method in Psychology, particularly in its physiological and anatomical relations."

SECTION G—PSYCHIATRY

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(*Hall 7, September 22, 10 a. m.*)

CHAIRMAN: DR. WILLIAM A. WHITE, Government Hospital for Insane, Washington, D. C.
SPEAKERS: DR. CHARLES L. DANA, Cornell Medical School, New York.
DR. EDWARD COWLES, Boston.
SECRETARY: DR. C. G. CHADDOCK, St. Louis, Mo.

PSYCHIATRY IN ITS RELATION TO OTHER SCIENCES

BY CHARLES LOOMIS DANA

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THE task of preparing an address upon the relations of psychiatry to other sciences presents some embarrassments. Psychiatry itself, in its narrower sense, is the science that deals with the phenomena of disordered minds. But the psychiatrist has also an applied science to utilize, or in reality a business to perform, which engages much of his energy, and is a very dominant thing in his professional life. This business is that of the administration and care of the insane, and it is hard to ignore its immense importance in discussing psychiatry from any broad standpoint.[1] Indeed, one may say that the most real advance in the treatment of insanity lies in the improved methods of hospital care that have been developed in the last thirty years. Still, the science of psychiatry, as pursued by the clinician and the pathologist, is that phase of it which must, for our present purposes, be set apart and its "problems" and "relations" studied.

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[1] Among 5470 contributions to psychiatry made during the five years, 1894–1899 (Jahresberichte für Psychiatrie u. Neurologie), the number devoted to different groups of subjects was as follows: General symptoms, pathology and etiology, 1749; special psychopathology and therapy, 1581; administrative methods and reports, 1286; forensic medicine, 854. Thus writings concerning administrative care make up over 20 per cent of the total literature of psychiatry.

I do not know how one can very well entirely separate these topics from each other, and I must be excused if I sometimes slip from speaking of a relation to dealing with a problem. After all, the thing desired in such an address as this is, I assume, to find out how psychiatry stands as a science now, what dependence it has on other sciences, and what help it needs from them or can give to them.

Twenty years ago I was a member of an organization for securing reforms in the care of the insane. It fell to me to present the situation then of psychiatry in America. It may be said that at that time little science of this kind existed here. This was so much the case that the superintendents of the insane asylums had withdrawn from affiliation with the American Medical Association, and had for years kept out of formal touch with general medicine and the activities of medical science. Psychiatry had mainly one side: the business of administration and custodial care. Only four medical schools pretended to give any teaching in mental disease in the whole country. There were then only 74 state asylums, with a population of 39,145 insane and considerably less than half of the insane of the country were in institutions designed for their care. The cost of running these institutions was about $200 per capita yearly, which is perhaps a fifth greater than it is now. So that psychiatry represented a business conducted in some places well, in some ill, as sentiment demanded or as money was supplied.

This situation was a natural one considering the state of public feeling and of medical science at that time; for the thing to do with the alienated, when only one thing can be done, is to take good care of them; after this we can study them and build up a science and an art. And this is what has happened.

During the last twenty years there has been steadily developing a science which deals with mental disease. Largely through the influence of certain clear-sighted administrators of our hospitals, our knowledge has developed until now we are justified in classifying psychiatry among the medical sciences, surpassing in exactness some, and in importance, interest, and difficulty perhaps all, of the other branches of medicine. For we are dealing in its study with the ultimate and finest and most elaborately differentiated product of organic life, and our task with it is not only to study and to classify, but to prevent and to save that which is most essential to human progress — the human mind.

During these past twenty years the administrative care of the insane has also steadily improved, so that now in our best semi-private and endowed institutions there is really little more that humanity could suggest or ingenuity devise for the comfort and care of the patient. In many of our state institutions there has been also a steady progress, which is hampered in some states by poverty and lack of intelligent interest, and in nearly all by the allied science of politics. Indeed, while this last exists, state hospitals will always fall a little short of the ideal. The psychiatrist stands on one hand striving to bring things up to his highest views, the politician on the other, urging something cheaper, and standing for an influence that tends toward mere custodianship.

The science of psychiatry comes in touch with many branches of human knowledge. In so far as psychiatry has a practical side, it stands in close relation with what may be called, in general, *economics;* to an extent, also, it is in relation with all those sciences which particularly tend to prevent and ward off insanity by improving social conditions through sanitation, education, and better heredity.

The science of psychiatry utilizes, at all times, the work of the psychologist, but, most of all perhaps, it stands in relation with certain departments of internal medicine, such as pathology, and chemistry. Psychiatry has also certain relations with the law, with the criminal, and in general with abnormal man.

To take up all these relations in detail would make an address very long and very desultory. Yet I do not see how, in the nature of the case, my remarks will not have some of both these characters. I shall, however, while touching on a number of topics, lay special emphasis on a few that seem most important.

Psychiatry and Economics

The relation of psychiatry to economics is one of increasing interest and importance. The loss to the state and the expense in money from disease is a subject that has received increasing attention of late years, until now in many directions public knowledge and state action are almost adequate to the problems involved. The results have been the extermination of some and the holding in check of other diseases. Thus, in the more advanced communities, with the exception of certain pulmonary troubles, and a few of the infectious and eruptive fevers, the prevalence of microbic diseases has been decidedly checked.

Nervous diseases, however, if we include also those due primarily to vascular disease, are probably more numerous than ever. Statistics are almost useless for determining this question, because there is no common nomenclature, the diseases are not notifiable, and, at best, we must go by death statistics. I believe it to be common medical opinion, however, as it is certainly my own, that both organic and functional neuroses are relatively more numerous than they were fifty years ago.

As to the psychoses, there is little doubt that they are also increasing, relatively, more than the population. This is shown in the reports of those states in which statistics have been more carefully kept, as, for example, in Massachusetts, New Hampshire, and New York, as well as by the census statistics of this country and Great Britain. We may say that in the last twenty-five years the ratio of sane to insane has shown an apparent gradual increase from 1 to 450 to 1 to 300, and this latter seems to be about the ratio in those communities of North America and Europe in which modern conditions of civilization prevail.[1] This average has varied but little in the last few years; the slight yearly increase probably will not change rapidly and probably not continue. For when the increase in the insane reaches a certain point of excess, society will have to take notice of it and correct it.

For twenty-five years the explanation for this increase has been that more cases were observed and more victims kept in institutions than formerly; and this is still the explanation. It is my opinion, however, that the increase is a real one, and it is one to be expected, not only from the strenuousness of modern life and increase of city population, but also because more feeble children are nursed to maturity and more invalid adolescents are kept alive to propagate weakly constitutions or to fall victims themselves to alienation; the period of life susceptible to insanity is longer.[2] A fourth of the cases of insanity are due to so-called moral causes: emotional strain, shocks, and vicious indulgences. But moral causes are not sufficient to cause insanity if the individual has a sound constitution. Insanity is increasing in part, then, because we are saving too many lives by the careful regulations of our health boards. Hence, those who are working so enthusiastically, and nobly, and successfully in preventing disease achieve results which carry serious responsibilities for the state.

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[1] The somewhat startling increase in suicide is corroborative of an increase in psychopathic constitutions.

[2] The expectation of life is now 43.59 (Newsholme). The death-rate of children under 5 has dropped from 68.6 to 64.5 in the years from 1865 to 1895 in Massachusetts. The drop in the death-rate, from 5 to 40, has been much greater, while the death-rate above 40 has increased. (S. W. Abbott, Vital Statistics, Wood's Ref. Handbook, vol. VIII.) The period of life during which insanity most frequently occurs is 30 to 40, and next, that between 20 and 30. The average age at death in England was:

	Males.	Females.
1840	27.15	29.38
1900	33.63	39.90

	Excluding 0 to 4.		Excluding 0 to 54	
	Males.	Females.	Males.	Females.
1840	46.46	46.77	72.09	73.05
1900	53.17	55.21	70.41	71.92

—S. G. Warner.

Expectancy of life in Massachusetts:

1880	44.64
1900	46.05

— U. S. Census Bulletin, No. 15.

The average age at death has increased from about 28 in 1840 to 34.5 in 1900, thus bringing more people into the third decade, which is the one most fruitful in insanity.

Let us see what the facts are regarding the economic loss of insanity :

There are in the United States now about 145,000 insane; 120,000 feeble-minded; a ratio of about 1 to 300.

The annual increment of insane in Massachusetts, according to the Massachusetts Board of Lunacy, is 400 in about 10,000, or 4 %.

At this ratio, the annual increment for the United States would be approximately, 5600.

The cost of maintaining properly these 145,000 can be estimated fairly on the basis of the cost of the institutions of the two large states (Massachusetts and New York), where it is admitted the work is at its highest efficiency.

The plant for caring for the 22,000 insane of New York is valued at $22,000,000 (Mabon), and the plants for caring for our insane, if we are desirous to care for them in the way creditable to a great civilized and wealthy nation, should be not less than $150,000,000. To run this national plant the cost is, at a moderate estimate, $3.50 weekly, per patient. This is about the average in New York and Massachusetts and most properly organized state hospitals elsewhere. This gives the insane no luxuries either; for the average cost of properly caring for the insane in private institutions is $12 to $25 per week. This with the interest on the plant makes the actual objective cost of caring for the insane of the United States every year about $40,000,000.

This does not include the care of the feeble-minded. So far as the state is concerned they are less of an expense because a large number are cared for in families. Many do not need actual responsible supervision, and many can in a degree support themselves. Finally, the feeble-minded are short-lived, while the insane live into and beyond middle life. At the best, however, the idiot or feeble-minded are persons whose lives are a burden and a sorrow beyond what is measurable in money. An idiot cannot be supported for much less than the insane, and it is safe to put down $20,000,000, yearly, as the sum we pay for having the idiot with us. But $60,000,000 a year does not represent all; 70,000 of the insane are men and presumably breadwinners. The average worth to a community of a healthy worker is about $400 a year. This sum is subtracted from industrial activity by his sickness. Assuming that the 70,000 insane men could earn this sum, we have a loss of $28,000,000 more per year. It seems to me that it would not be far out of the way to say that the care and cost of the diseased and defective brains of the country is over $85,000,000 annually, and is increasing absolutely at the rate of 4 %. These figures, perhaps, are not so very alarming to a nation with an income of $600,000,000. It is a sum that would not quite run the city of New York, or support an army or navy. But it is an item to be reckoned with by economists; and the side which cannot be represented by figures is still more important, viz., the sorrow and suffering and indirect loss in health and happiness.

If there were a science of state medicine, the economic study of insanity which brings out some such figures as those I have just presented would be called into demand.

State medicine in some of its branches is supposed to give us means of relief from social evils due to disease. In the case of insanity it would have to call upon various minor divisions of science for help. The study, for example, of the causes of insanity, teaches us that if we could subtract alcoholism from our social life, and nothing took its place, we should cut out about a tenth of the cases of insanity brought on directly by this poison. We should probably subtract a large number, brought on directly through alcoholic parents. If we could subtract syphilis from our civilization, we could cut out a tenth more of the insane. If we could do away with violent passions, shocks, mental strains of various kinds, we could cut out perhaps 25 % more of the insane.

But after all, supposing even these practically impossible feats could be accomplished, there would still be left a large percentage of the alienated, and this percentage would include persons who developed disordered minds because they were born with a tendency to mental degeneration.

It follows that the most immeasurably important factor in attempting to limit and prevent insanity is to secure well-born children; to see that those people who have weakly constitutions, or poisoned constitutions, do not propagate the kind. This is, of course, a thing which can only be accomplished by long years of careful education and training. The science of *eugenics* is hardly yet existent, and if it were a full-fledged science, the people are not educated to receive its teachings. There are, however, known to be certain fundamental principles of "eugenics" which cannot be too strongly insisted upon. One of these is that persons who have strongly alcoholic tendencies, or who are dipsomaniacs or drug-takers, are almost sure of breeding degenerate children. And the same is true of those who are plainly syphilitic, or who are on both sides tuberculous, or on both sides psychopathic or neuropathic. One further point only I wish to make in connection with this subject, and that is the question of the results of the amalgamation of races in this country. While the ratio of insanity in the United States is fully up to that of other civilized nations, it is not especially in excess, hence it cannot be said that the fusing of different races here has yet caused deterioration. Nevertheless, it is a practical and serious question as to what will be the eventual result. We know that when widely different races, like the African and Aryan, mix, they do not breed good men and women.

We know that, on the other hand, races such as the Jewish and the Japanese, which have kept themselves pure for centuries, have reached a very high stage of efficiency. So far as history shows, we have no clear proof that the mixing of races breeds races of a higher efficiency. But we do know very well that the mingling of very widely different races leads to a degenerate quality of hybrid. What will be the result of fusing together the typical Anglo-Saxon with the dark-haired Latin, Slavic, and Semitic races of Southern Europe, remains to be seen. Since they are all of Indo-Aryan stock, no harm may result, but I have personally observed most disastrous results among children of unions between the Scandinavian and the Spanish races.[1]

Psychiatry and Psychology

The science of psychology stands nearest to psychiatry of all the non-medical sciences. It should, in fact, bear the same relation to clinical psychiatry that physiology does to medicine. It furnishes us the normal standard of mental activity, and should give name and definite description of what takes place in the healthy mind. Therefore, it is as important that the psychiatrist should have a sound knowledge of the elements of psychology as that the neurologist should know the anatomy of the nervous system.

For after all psychiatry is now and will long be essentially a clinical science, a study of a grouping of symptoms. In neurology we make three diagnoses when the art is perfectly exhibited. We have a clinical diagnosis by which we recognize a symptom group, a local diagnosis by which we recognize the seat of the disease, and a pathologic diagnosis by which we recognize the nature of the trouble. In psychiatry only the clinical diagnosis is made as a rule, and this clinical diagnosis is really dependent mainly on the study of the psychology of the patient. Clinical psychiatry is, in fact, only morbid psychology.

All this would lead us to think that the relation of psychiatry and psychology should be an intimate one. As a matter of fact, psychologists do not write with much reference to the morbid mind. This at least is my experience in an effort to orient myself on this subject.

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[1] In a study of the subject of immigration and nervous and mental diseases, made in 1882 (*Annual Report* of American Social Science Association), I reached the conclusion that immigration tends slightly to increase the amount of insanity out of proportion to the native population, partly through influence on social life and partly through the introduction of poor stock.

Only a portion of the immigrants and certain special races have these tendencies. Immigrants were found to develop an excess of organic disease, but to have fewer functional nervous diseases than natives, due probably to their social conditions and the exposure incident to poor methods of living.

Twenty years ago the foreign-born made up a fifth of our population, and contributed to a third of the cases of insanity.

We as alienists do not need a large vocabulary or very recondite knowledge of psychology. We do not require to hold opinions on association theories, or on parallelism or monism, or epistemology.

We do very much need definite descriptions and harmonious views of the elementary mental processes.

We deal in disorders of sensation and perception, in failures of memory, perversion of judgment, states of feeling either too intense or depressed, loss of the volitional function, and disorders of instinctive reactions, of memory and of consciousness. Yet it is not easy to find these states clearly defined among psychologic authorities. I have a list of the psychologic terms used to describe groups or individual symptoms in psychiatry. This vocabulary of involved symptoms has only about twenty-five terms, but they mean different things according as the physician takes his psychology.

Psychiatry is having its great difficulty in classifying its cases. Practically every writing alienist has a special classification of his own. This is in part because cases cannot be observed completely or recorded thoroughly without a proper language for recording the facts. The older alienists never knew the science of psychology, because there was none; the modern are only learning it. A thorough and especially a uniform understanding of psychology is necessary in order to give sharper definition to observed phenomena, to bring out new facts and to clarify the symptomatology and make us agree upon our groupings. For example melancholia used to be considered as essentially a morbid depression of the mind. Now we know there are other elements such as retardation and difficulty of thought and action, of disturbance of attention and volition; we find, in fact, that there may even be a melancholia without any melancholy. It is in the observation of the often obvious psychic states and in the correct record of all deviations that we may expect to make real progress. And we need a uniform psychologic vocabulary for our purpose, as well as a pretty thorough psychologic training.

I have collected from the writings of Stout, Morgan, James, Baldwin, Ladd, Calkins, Titchener, Sully, the definitions or views given by them of the elementary and other mental processes:

Sensation, impression, perception, percept, conception, concept, image, idea, ideation, judgment, reason, reasoning, emotion, feeling, sentiment, conation, will, volition, consciousness, memory, association. There is substantial agreement about the significance of perhaps the majority of them, and I quite understand that the mind is not to be divided into sharply limited mental processes, but that mental states are all complex and that one process overlaps another.

Nevertheless, there are decided differences and vaguenesses in the views of sensation, perception, of concept, memory, image, idea, will, consciousness. The establishment of a better relation between psychiatry and psychology is at any rate a thing much needed, but belongs, perhaps, to the problems of psychiatry.

The following are examples of the differences in the definition of elementary psychological terms among leading psychologists.

Impression is the simple result of a stimulus. (Morgan.)

Sensation is the discrimination and recognition of the impressions as of such and such a quality. It is the reception and discrimination of impressions which result from certain modes of stimuli, like sight, hearing. (Morgan.)

Perception is the process by which sensations are given objective significance, being supplemented by revived sensations. (Sully, Morgan.)

Perception always involves sensation. (James.)

Percept is the aggregate of the revived and actual sensations, integrated and solidified. (Morgan.)

Perception (Wahrnehmung, Anschauung):

(1) Cognition, so far as it involves the presence of actual sensation as distinguished from mental imagery.

(2) Cognition of subjective process as such; the apprehension of the actual presence of this process in distinction from the ideal representation of it. (Stout, Baldwin.)

The old writers used perception as a synonym for cognition in general. The later tend to fuse sensation and perception. Some speak of inner sense, inspection or introspection as perception.

Perception (Wahrnĕhmung) is the process of the apprehension of sense-objects.

Anschauung is rather sense-intuition. (Baldwin, *Dictionary of Psychology.*)

Memories of percepts are simple, particular or concrete ideas. (Romanes.)

Image (Bild). The mental scheme in which sensations or the sensory elements of perception are revived. (Baldwin, Stout.)

Idea (Vorstellung). The reproduction with a more or less adequate image of an object not actually present to the senses. (Stout, Baldwin.)

A mental image is an idea, according to Ladd.

The German *Vorstellung* is sometimes used to cover both perception and idea, and there is a tendency to give the same wide application in English. (Titchener, *Outlines of Psychology.*)

In a perception the object perceived is usually supposed to be present.

Ideas which are general and abstract are concepts. (Romanes.)

Ideas which are complex, compound, or mixed are recepts. (Romanes.)

Ideation is the elementary mental process involved in all work of the representative faculty. The products of this are mental images or ideas. (Ladd.)

Conception is the function by which we identify a numerically distinct and permanent subject of discourse. (James.)

Concepts are the thoughts which are the vehicles of conception. (James.)

A *concept* is a general notion or general idea. (Sully, Romanes.)

A *concept* is an image or general idea into which there have entered elements which have been isolated by analysis. The term *soldier* may stand for a percept or concept according as there are associated with it qualities not identified with a particular *soldier.* (Morgan.)

A *concept* (*Begriffbildung*) is cognition of a universal as distinguished from the particulars which it unifies. The universal apprehended in this way is called a *concept.* It unifies a distinction between the universal and the particular.

In philosophy it is common to apply the word more widely, so as to cover the universal element in knowledge, *e. g.*, the categories of Kant were called *concepts.*

In psychology, John Roe is a particular concept; a triangle is a general concept. (Stout, Baldwin.)

Reason, in English, means often reasoning or reflective thought, less often intuitive and certain knowledge. (*Dict. of Psychology.*)

Reason is a form of knowledge which apprehends in one immediate act the whole system, both premise and inference, and thus has complete and unconditioned validity.

This distinguishes it from understanding (*Verstand*), which is a form of knowledge that is discursive, and hence based on premises and hypotheses not themselves the basis of reflection. (J. D., *Dict. of Psychology.*)

Reason (*Verstand,* λόγος) is that faculty or process of mind which consists in the drawing of inferences. (G. E. M., *B. Dict. of Psychology.*)

There are other more restricted definitions given:

Reason is to pass from certain judgments to a new one. (Sully.)

Reason includes the formation of a judgment or concept, not inference, then passing from it to a new one. (Morgan.)

Judgment (*Urtheilskraft, Urtheil*). The mental function and act of assertion and predication. The term is also applied to the resulting assertion as well as to the process or function. Judgment as a mental process is similar to belief. (Baldwin.)

Modern psychologists find it difficult to define belief and judgment without overlapping, and French psychologists class delusions or false beliefs as disorders of judgment.

Judgment is a conscious mental synthesis, a unifying act. (Ladd.)

Judgment is an inference in the form of a proposition. (Morgan.)

Conation (*Streben*). The theoretic active element of consciousness, showing itself in tendencies, impulses, desires, and acts of volition. "Conation" in general "is unrest." The term will (*wille*) is often used in the same sense.

Streben is translated *effort* by Titchener.

Begehren is used for *conation* by others. (*Dict. of Psychology.*)

Volition is the faculty of the forked way, the possibility of action or inhibition. Man has perceptual volition, in which he is conscious of a choice, but does not reflect upon it. He has conceptual volition, in which he is conscious of choice, and can reflect upon his choice. (Morgan.)

Volition is a definite conative activity consciously directed toward the realization of some mentally represented end, preceded or accompanied by a desire, and usually accompanied or followed by the feeling of effort. (Baldwin, Stout.)

The settlement by the self of a psychic issue, the adoption of an end. (Baldwin, Stout.)

Will is that conative organization of which volition is the terminus or end-state. Will is conation in the concrete, determined in an actual terminus by volition. (Baldwin, Stout.)

Emotion (*Affect*). A total state of consciousness considered as involving a distinctive feeling-tone, and a characteristic trend of activity aroused by a certain situation which is either perceived or ideally represented. (Stout, Baldwin.)

Feeling or feeling-tone (*Gefühl*) is absolute emotion.

The same conscious state may be regarded either simply as feeling, emotion, passion, or sentiment. (Ladd.)

Consciousness (*Bewusstein*). The distinctive character of whatever may be called mental life. It is the point of division between mind and not mind. (Baldwin.) Whatever we are when we are not unconscious, that is consciousness. (Ladd.)

Earlier psychologists called it the mind's direct cognizance of its own states and processes.

The word is not even indexed in Calkin's *Elements of Psychology* and is not defined by James.

Consciousness or *awareness* means, according to G. Spiller, that a notion does not stand by itself, but is connected to another notion; the word "connection" may better be used for it.

Psychiatry and Physics

The science of physics is in closer relation to the administrative care of the insane than to psychiatry proper. Light and electricity have as yet little to do with our pathology, and not much with our therapeutics. We are watching, however, with interest, the various newly-discovered light-rays and their influence on bodily function, as well as the new conceptions of the elements, and their possible bearing on the physiology of the mind.

So far the medical and surgical effects have been superficial and have produced results only on gross and objective evidences of disease, such as tumors, ulcerations, etc. Some claims have been made that the Röntgen ray will relieve pain in neuralgia and tabes, will lessen or check convulsive attacks in epilepsy, and have a real physical effect upon the lymphatic and glandular tissues, as in thyroidism. It is not impossible that some forms of radiant energy passed through the nervous centres may modify the metabolism and produce therapeutic results, but this is speculative, and it is not likely that, at the best, much can be accomplished.

It seems to be well established that very rapidly alternating electric currents of enormous voltage, when passed through the body, increase metabolic changes, but here again nothing very definite has yet been achieved therapeutically.

The problem of helping the alienated by physical means is a serious one — it means that we must change a psychopathic constitution so that a person who has a melancholia or is threatened with it will be rid of the disorder and of the tendency to its recurrence. Some readjustment of glandular activity of the liver or stomach, or some increased activity of absorption and secretion and elimination, must be secured, or by some subtle influence we must teach the brain-cells to build up and break down in a normal and well-balanced manner, or by specially directed training structural defects in the arrangement or insulation of the neuron must be overcome.

Here is a field in which the finer physical forces may play a part, and we already know that the influence of direct sunlight is helpful in delaying degeneration. Other physical agencies may be found which will furnish more.

I can only suggest the possibility that in psychic activity there may be radioactive changes, a breaking-up not only of molecules which we know occurs, but of the atoms themselves. This hypothesis is in the line of the alleged *n*-ray phenomena of Blondlot.

Psychiatry and Psychotherapy

It is a popular question whether the mind does not produce more diseases than do organic changes of the body. In fact, the supporters of the belief that the mind is more important than the microbe make a large cult in this country.

I do not know that the question really deserves very serious consideration. A little acquaintance with dispensary and hospital practice and the records of the health boards is sufficient to show that mental states rank far below the infections, poisons, inflammations, or injuries as makers of symptoms among all classes. I think it would be safe to say that the general practitioner meets a real objective disease twenty times to one in which the symptoms are due to the attitude of the mind. The mind disturbs functions and creates symptoms, but it muddles rather than makes disease. To be sure, it is indirectly a potent thing. Thus, in conditions of profound depression there is a lessened vital and circulatory resistance, and infection can creep in. It would never do for physicians to fight an epidemic with cold hands. Conditions of the mind can favor or delay digestion and peristalis, and there is, indeed, no function more susceptible to physical control than the chylopoietic tract. One can almost stop digestion by taking thought of it, and the influence of mental treatment and sugar pellets upon constipation can be given objective proof in many instances. The mind has, in fact, quite a lively though incomplete and temporary control over the different functions of the body, and it can, after years, do some damage to them. It can check and change secretions, indirectly thicken arteries, cripple functional activity, and hurry on old age. But after all, the mass of people are sick with tuberculosis, rheumatism, bronchial and heart diseases, and the infections and the injuries of life.

As the mind can help on disease, so it can help on its cure; but a healthy person cannot by an act of his mind make himself crazy; and neither can he by any mental influence, if crazy, make himself well. It has been proved beyond any question that persons who have severe and profound degenerative traits cannot be cured by psychic suggestions.

Hypnotism, for example, is powerless against the insanities after they have developed, it is powerless even against the minor psychoses that are long established and of severe type, such, for example, as chronic hysteria, the long-established obsessions, vicious mental habits, and severe degeneracy. What is true of hypnotism is true of all forms of mental therapeutics, and all types of charlatanry that appeal to the imagination. It may be noticed that the quack and the exploiter of marvelous cures never starts a psychopathic hospital or offers to work in an insane asylum. When the mind is a little enfeebled, over-sensitive, or untrained, it is easily worked upon by emotional influences and suggestions; when it is sound, and trained by education and experience, and when it is seriously disordered, it is not affected by these agencies. Psychic measures of treatment, on the whole, find their legitimate field in internal medicine, among those who have the minor symptoms and functional disorders in which the mind is simply needing instruction to a new point of view, or the stimulus of a strong hope which fixes attentions and steadies the whole mental machine. Psychic therapeutics often cure by giving faith and purpose to the weak, wavering, and discouraged. And faith in something is always a sane and most helpful element in a person's character.

So far as psychiatry is concerned, we can expect little help from the science and art of psychic or hypnotic therapeutics. Its field is narrow and does not take hold of our serious cases.

So far as internal medicine is concerned, mental influences produce many distressing disorders of function, which may simulate various diseases. The mind is a factor always in modifying the picture of disease, and the physician can never diagnosticate or treat his patient without taking the individual's mental attitude into account. This fact, which psychiatrists learn, can be impressed with advantage on the followers of internal medicine.

Psychiatry and Neurology and Internal Medicine

In the past the field of work of the psychiatrist has been perforce much narrowed through the necessities of psychiatric administration. It was long confined to the study of types of mental disorders which had reached their height and shown their hopelessness. It was as though pulmonary tuberculosis had been mainly studied in its third stage, or typhoid fever mainly in its second week, or heart disease after dropsy had set in. For when a psychosis is fully developed and has bloomed into mania, or a dementia, the morbid condition has arrived, the god is no longer behind the machine, but on it. It can now be watched and its natural history studied, but in 75% of cases this is all; it cannot be cured. In only a small percentage will it be possible to learn why it came, and psychiatry can only reach a certain stage of progress when its study is limited to the middle and terminal parts of mental disorders.

The field of psychiatry needs thus to be broadened by securing the help of those branches of internal medicine in which the earliest phases of mental deterioration and disorder show themselves. It was long ago noted that neurasthenia might be called an abortive paranoia. It is my experience that about a third of the cases of decided melancholia are preceded by attacks of what is called nervous prostration; and the same is in a measure true of the early demential psychoses and of paresis.

In fine it seems to me that a most fruitful practical field just now for clinical study is that of what I term the minor psychoses which includes a vast number of indeterminate mental conditions, classed as neurasthenias, hysterias, phrenasthenias, obsessions, impulsive manias, and mild melancholic and hypochondriac states. These patients now fall into the hands of the general practitioner, who is wearied and unimpressed by them, and who fails from lack of interest to study them, or into the hands of specialists who treat their reflexes, generally without avail, or into the hands of neurologists who deal with them generally as having a temporary neurosis instead of a psychosis or the thing out of which one may grow. It is to be hoped and expected that the follower of internal medicine and the neurologist will study the cases more seriously, and from the point of view of the psychiatrist especially. In this way we shall be able to learn the very earliest symptoms that suggest the oncoming of mania and dementia praecox; we will learn better the type of infancy and childhood out of which it grows; we shall learn how to check and to prevent it.

An illustration of such help of neurology and syphilology to psychiatry is already shown in the development of our knowledge of general paresis. This disease was recognized a hundred years ago. Its etiology was not even distinctly suspected till fifty years ago. An established connection of its relation to lues is hardly more than ten years old, this being worked out by the coöperation of the syphilographer, the neurologist, and the psychiatrist. New features of its course, particularly the physical symptoms and early symptoms, have been derived within a few years largely through the help of psychiatrists, neurologists, and syphilographers working together, until now the onset of disease is recognized almost before it is present. By reason of this its course has been checked, and it is my belief that cases have been permanently arrested in their progress, so that we may now say that paresis may sometimes be aborted, if not cured. All this has been done through the coöperation of alienists, neurologists, and syphilographers.

So it seems to me a like coöperation will enable us some day to cope with mania melancholia, chronic melancholia, and the precocious dementias. In this work we must have the help of the practitioner of children's diseases, of the general practitioner, and of the educator who studies the growing child.

A great deal of work has already been done in measuring children, studying their growth, their mental activity and reactions, but not much has yet been formulated which is helpful to us as psychiatrists, to foresee a coming psychosis.

This field needs further study from the anthropologist and the doctor of infancy and childhood. We do not want to know alone that a child is nervous, excitable, easily febrile, a bad sleeper, and a noisy dreamer. But what are the special symptoms which may lead us to foresee a dementia praecox at eighteen, or an hysteria, or a mania melancholia before adolescence, or a paranoia at maturity?

Psychiatry, Pathology, and Physiologic Chemistry

There is an increasing conviction among psychiatrists that some inherited defect, often most subtle and difficult to recognize, is present in all those who develop mental disorders without some original weak spot in the psyche or soma, the man who is infected will not get paresis or tabes; the man who has fevers, toxemias, shocks, and emotional crises, will not get a delirium or insanity.

But the weak point in a degenerate constitution may not be especially in the nervous system. It may be in a glandular defect or insufficiency. One can imagine a person having congenitally defective adrenal glands; as a result, the blood-vessels are not kept at their proper tonicity, and widespread defects in function follow. In the same way, there may be defective or overactive thyroids, and the tonus of the nervous system is disturbed. There is no doubt that the large colon has important functions in selective absorption, and to an extent in secretion. It is an organ that seems especially attuned to cerebral states. It goes wrong at times with every one, but if it is congenitally wrong, if it is born wrong, it is then one of the stigmata of degeneracy. Thus a person may have a psychosis, because he has congenital defect in the colon or other organs than his nervous system; the brain may be a very good one, but these adrenal organs — the thyroids, the blood-making organs, the enteric membrane, the liver — may be fundamentally defective or the circulatory organs may be badly developed.

Now it will be the part of the clinical pathologist and chemist as well as of the anatomist to search out these factors, and in this way help the psychiatrist to steer his way in the future.

I do not believe that the results of this work can be very fruitful as regards the severe dementing forms of mental disease; here there is always fundamentally a fault with the brain in structure or function. But in the functional and non-dementing psychoses, such as mania and melancholia, and in the minor psychoses, such as hysteria, many types of neurasthenic insanity, we may expect much help.

Insanity, on the whole, is not a very curable affection. It is probable that less than a fourth get permanently well, and its rate of cure is therefore less even than that of pulmonary tuberculosis, pneumonia, or the infective fevers. Nor is it likely that the percentage of cures will ever be a very high one.

We may look to the sciences of pathology and chemistry, however, for some help in this direction. It has been already shown that in degenerative disease of the nervous tissue there is the perverted metabolism, which leads to the breaking-up of the lecithin, the important fat constituent of the nervous substance, into poisonous by-products, neurin and cholin. These circulate in the lymphatics and blood-vessels and irritate and further poison the nerve-centres. So that when the brain actively degenerates, it produces a poison. This poison reacts on the nervous centres, causing new symptoms, and thus a vicious cycle is set up. Some of the crises of paresis and the dementias may have this origin.

The function of the lower bowel seems to have some close relation with the functioning of the nervous centres, and an autotoxemia is perhaps an important element in both depressive and maniacal states. Indeed the appearance of mania especially suggests an auto-intoxication. One cannot observe the apparently causeless recurrence of mania and melancholia without the conviction that behind it all is a disorder of metabolism leading to a toxic state.

We may expect, therefore, much from the further studies of the physiologic chemist. Such studies will include the activity of the ductless glands, the adrenals and thyroid, and in particular of kidney.

We cannot, it is true, expect to find any objective explanation of the tendency which the alienated possesses to pass repeatedly into states of mania. But we may find the nature of the nutritional change that excited it, and by proper methods we may be able to keep off recurrence of insanity.

This it seems to me is a hopeful field of therapeutics which is now presented to alienists.

The clinical pathology of the blood has as yet been of little help in psychiatry. The examinations throw no light on the cause or type of a psychosis. Nor do clinical pathologists promise us much here. If we could find and cultivate the germ of syphilis, a field would be opened. At present there are no biologic blood-tests that help us. It seems as if the ingenuity of the investigator would some day in some way show us objectively some blood-changes, for example in acute mania or delirium — yet it has not been done.

Pathologic anatomy is a subject of more academic than practical interest to the psychiatrist. The burden of our work should now be away from morpholgy and more in physiologic lines.

Psychiatry and Criminology

The relation of psychiatry to criminal anthropology is a close and important one. There is on the one hand the instinctive or hereditary criminal, and on the other the moral imbecile and the insane who do criminal acts perhaps casually or as an accidental product of violence and delusion. It is for the psychiatrist to help in solving the difficult problems of the border-line cases. As a rule we can say that the criminal's act has a definite motive, and that his crimes are to his temporary or apparent advantage. The moral imbecile, on the other hand, is in most cases a person whose acts are done without rational motive, or are to satisfy only some morbid feeling, perhaps remotely sexual, perhaps something not easily defined, a kind of atavistic lust-hunger.

But no definite laws can yet be laid down. Each case must be studied by itself in the light of our best clinical knowledge of what constitutes an insane mind. We must bear in mind in doing this that society cannot on the one hand afford to be cruel, and on the other it cannot afford to set aside easily individual responsibility.

For the purpose of securing the ends of justice in any of these cases, such laws as have been enacted in Maine, New Hampshire, and Vermont, and especially in Massachusetts, are best calculated to help on the aims of justice. These laws authorize the prosecuting attorney or judge to place the accused in a hospital where he can be under constant surveillance of physicians, trained experts, and attendants.

The Massachusetts law, for example, reads as follows:

"Chapter 219, Section II. If a person under indictment for any crime is at the time appointed for trial, or at any time prior thereto, found by the court to be insane, or is found by two experts in insanity designated by the court to be in such mental condition that his committal to an insane hospital is necessary for the proper care or for the proper observation of such person pending the determination of his insanity, the court may cause him to be committed to a state insane hospital for such time and under such limitations as the court may order."

Psychiatry and Forensic or Legal Medicine

Forensic or legal medicine as a separate branch of science seems in a way to have died out. It used to be systematically taught in a number of our medical schools, but the chairs have been abandoned. This is not because the subjects which are dealt with have ceased to be of importance (from 1894 to 1899 there were 854 contributions to the forensic medicine), but because they have been assigned to different specialties — the chemist, pathologist, psychiatrists, neurologists, and lawyers. Forensic medicine has been broken up into special branches and hardly exists any more as a particular department of human knowledge.

Psychiatry has much to do with the law, however, and some forensic medical knowledge may be considered almost a part of the requirement of a psychiatrist. Happily, the harmonious coöperation of law and medicine in the professional activity of the alienist is an object that has been fairly well attained, so far as regards the care and guardianship of the insane is concerned. Thus, the matters of commitment, detention, guardianship, discharge are problems fairly well solved in many states, and their discussion is not in the sphere of my address. I can but express the hope, however, that the tendency of legislation will be to lessen the restrictions and simplify the legal methods connected with the care of the insane. It should be easy to get into a hospital and easy to get out. The insane should more and more be considered as sick persons, which they are, and treated as nearly as possible on such lines, both by the doctor and the lawyer.

Psychiatry and Anthropology

The results of the work of anthropologists of the Lombroso school have been fruitful to penology and the saner and more rational dealing with criminals; but they have so far not been of much help to the psychiatrist. The elaborate measurements and observations which have been made show a larger number of anomalies and marks of deviation from the normal in the insane as a class than in the healthy. But these stigmata are never sufficient of themselves to justify one in saying that an individual is defective, or degenerate, or insane.

In some very marked types of insanity they are practically absent. This is especially true of insanities that develop late and have slight dementing tendencies. Insanities with decided moral defect, such as those known as original paranoia, or moral insanities, those characterized by obsessions and compulsions, also show often few stigmata of degeneration. Those with decided intellectual defects and dullness have a large percentage of physical marks. Such, at least, has been my observation.

The science is still young and it should receive the support of psychiatrists. This is being given in some hospitals of this country. An anthropologic laboratory, even if but a modest one, should form part of the equipment of the psychopathic hospital. And observations should be made not perfunctorily and in accordance with some limited conventional plan, but with great attention to detail and with minds open and ready for advance and change. The simple accumulation of fifteen or twenty measurements and notes has been done until it has nearly fulfilled its usefulness.

The foregoing remarks do not lend themselves to recapitulation. I have endeavored to show some of the relations of psychiatry to its nearest allied sciences and to indicate the lines along which work can be carried with mutual help to all, but to the special advancement of a sounder knowledge of that capstone of all the medical sciences, the pathology of the mind.

THE PROBLEM OF PSYCHIATRY IN THE FUNCTIONAL PSYCHOSES

BY EDWARD COWLES

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IN the study of mental diseases it is important to find their true place in relation to other pathological conditions. Our conceptions of the nature of mental symptoms should be framed in harmony with the true principles of general pathology. These are essential requisites for the progress of psychiatry. I shall try to present some considerations to this end in discussing my subject: "The Problem of Psychiatry in the Functional Psychoses."

It is essential here, as in all such inquiries, to have a clear understanding of the terms of the problem; words and phrases, and the formulae of principles, should have correct and definite meanings. Our ideas may be embodied at first in words which seem to express exactly all that we know; but as our conceptions tend to outgrow their verbal expressions, these may gain the larger import and lose the narrowness of their derivations; or being used in an earlier and more or less restricted sense they hamper thinking in the shackles of authoritative phrases that obstruct reasoning, and single words may perpetuate error and lead to confusion of interpretation and discussion. The dicta of general principles accepted as fundamental may sometimes harbor hidden fallacies and prove to be untrue after having long retarded progress. It is a necessary part of this discussion to examine first some definitions and the formulae of certain accepted principles and the doctrines drawn from them.

The terms in which the present subject is expressed contain no ambiguity as to its meaning to lay down the proposition that the problem of psychiatry is to be found in the functional psychoses, meaning here mental diseases. But something needs to be said defining the true province of psychiatry; and the words "functional psychoses" lead at once into the maze of difficulty surrounding the relations of functional and organic diseases. In the definition of disease, as "any morbid deviation from normal health," "the important distinction is drawn between organic or structural diseases in which there is a lesion or pathological condition of some part of the body, and functional diseases in which there is an irregular action of a part but without organic abnormality." But keeping to this distinction it is a remarkable fact that the word "psychosis" is used in opposing senses in mental physiology and mental pathology. The psychologists, having regard to the normal processes, use "psychosis" as "equivalent to the mental or psychical element in a psycho-physical process, just as neurosis refers to that aspect of the process which belongs to the nervous system." On the other hand, in psychiatry the word "psychosis" is used pathologically and "designates an abnormal mental condition;" it is described as a typical form of insanity ("disease-form") which can be scientifically differentiated and correlated with a specific "disease-process," and the usage implies a structural change. In neurology "neurosis" is also changed from its normal functional sense in psychology and used to designate a "morbid or diseased condition." "Functional neurosis is a morbid affection of the nervous system known only by its symptoms, and without anatomical basis. It is doubtless true that an anatomical lesion of some kind does in each case exist, and the classification of diseases as organic and functional is but a concession to our ignorance."[1] These instances afford examples of looseness of usage in two most closely interdependent lines of research showing the disharmony between them that tends to confusion of understanding. It is allowable to speak of the neuroses, and the meaning is plain as referring quite exclusively to functional disorders; but to constitute a true psychosis, in the pathological sense, it must have a definitely differentiated symptom-complex that can be designated as a "disease-form;" this is commonly spoken of as a clinical "entity," and it implies a correlated "disease-process." We may speak of acute and chronic psychoses, or of organic psychoses, to distinguish the insanity due to cerebral disease. But the psychoses proper being conceived as real disease-entities, when in psychiatry we wish to speak of the group of minor and often temporary variations of the mental functions, parallel or corresponding to the neuroses in neurology, the word functional must be added and the term functional psychoses used as in the subject of this discussion.

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[1] Baldwin, *Dict. of Philos. and Psychol.*

The Position of Psychiatry as shown by Current Teachings

The point of view of this inquiry is that of general medicine for one who, without predilection and looking for light on all sides, approaches the field of psychiatry and tries to understand its problems. In seeking the true place of mental diseases in relation to other pathological conditions, and in order to harmonize his conceptions with the true principles of general pathology, it is found at the outset that the functional psychoses are to be regarded as being in contrast with the psychoses proper associated with assumed structural changes and "disease-processes," or with definite organic diseases of the brain. Here as in general medicine this distinction of functional and organic disease appears to be an expression of the dominance of morphological conceptions in medical knowledge. Diseases due to obvious structural changes can be understood and subjected to treatment as in surgery; but the bodily diseases called functional for which there is no pathological anatomy constitute a very large group.

Although there is a greater reason for this being true also of functional mental diseases, the inquirer finds in the psychiatry of the time small interest in them. It is a very old idea that the different forms of insanity may be explained by the study of the brain and its degenerations. The history of modern psychiatry shows that it has given great emphasis to these morphological conceptions by its precise methods and achievements in histological investigations of the brain. In recent years the German schools have been the centres of interest. The environment of their origin had preëminently the morphological stamp. Thus the effort to determine definite "disease-forms" and "disease-processes" has been a distinctive characteristic of modern teachings in the search for anatomical correlations and explanations. The application of the scientific method in clinical study has been most fruitful of admirable results. The "disease-process" assumption has been stimulating and helpful as a spur to morphological investigation, which all agree should be carried to the utmost. But with the inheritance of such conceptions the modern movement has been characterized also by the continuance of the quest for mature forms and types and for their systematic classification. The pathological principles being embodied in the designations "disease-form" and "entity," and "disease-process," the consistent use of these has implied that every such pathological process should have its cause, course, and outcome. A psychosis thus constituted is held to present the attributes of scientific truth, although some actual morphological characters that furnish complete and proper proof may yet be wanting.

While these teachings have been taking form in the last twenty years, the influence of modern psychology has been felt and is becoming apparent, especially in the last half decade. Although psychological studies of mental functions are viewed with much of the same distrust as before, the experimental method, in its clinical use in psychiatry, excites interest by the objective character of its results; they have the value of observed and measurable facts of function which may contain the promise of being ultimately traceable to facts of structure.

The present results of this movement are exceedingly interesting and promising, although it is true that there is much diversity in the products of these methods of study. With the increasing number of observers the more variations there appear to be in the interpretation of phenomena. This is shown in the differentiation of named "disease-forms," and by a comparative study of some new classifications.[1] This, however, is a hopeful stage of progress. In the extreme view it has been held to be unreasonable that any conclusions can be drawn from the psychical activity of a diseased brain; psychological explanation is of no value, it is said, without an objective measure in definite "disease-processes" in the cortex. According to other views, in which the conceptions of a "disease-process" is still fundamental, conditions that do not lead to deterioration are conceived to be of a "special type," and a "biological entity" is conjectured as representing "a special kind of disease-process or disease-principle." Again under broader conceptions it is held that more than one point of view is needed to do justice to psychiatry, and a special psycho-pathology is founded upon normal psychology. But this meets with criticism as giving undue prominence to psychological distinctions inconsistent with a true medical conception of disease.

The influence of the new German schools has been strongly felt in other countries. But the inquirer, extending his survey in these directions, finds that the contemporary interest in the physiological aspects of psychiatrical problems has not waned, though they are somewhat overshadowed. In Italy, for example, Ferrari has studied the pathology of the emotions, as has Féré in France, where Ribot has done the most to elucidate the relation of mental experience to the personality, and Janet has made his remarkable contributions to future psychiatry by the analysis of mental instability in the borderland of insanity. The British alienists have conservatively given attention to functional as well as to anatomical conceptions, notably Mercier. Hughlings Jackson has magnified his distinction as a neurologist by his recognition of the importance of the physiological factors in nervous and mental disease; his method of reasoning from functional characteristics to interpret structure, instead of inferring function through proofs in structure, is now attracting renewed interest.

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[1] Meyer, A., *A Few Trends in Modern Psychiatry, The Psychological Bulletin*, vol. I, 1904.

These English views have long held a like formative place in America where they have not lost but have sustained their force during the decade since the introduction of German teachings. Attention was first attracted especially to Kraepelin and the methods at the Heidelberg clinic with a consequent intensification of interest in morphological conceptions qualified by clinical observation. The painstaking studies of Meyer and Hoch approached the subject from the neurological side loyal to the scientific method; through their work the conceptions of Kraepelin were submitted to the tests of practical coöperative study and experience with results anticipating his own later simplifications of "disease-forms." There was also, not only the establishment of collections of admirable clinical records, valuable for further study and analysis in future, at the McLean Hospital and the Worcester Insane Hospital where this special work began, but the extension of this clinical method to many other hospitals. Later in the movement came the different interpretations of psychiatrical problems by Wernicke and Ziehen, — the latter with an especially hopeful attitude toward psychological explanations. There has appeared a tendency to change in the views of these German teachers, of whom it is said they "have emancipated psychiatry from the peculiar position of an adjunct to neurology," — a position for which the claim has long been made and is not yet yielded.

In the outcome of the decade in America the intensity of the new teachings is being qualified by independent studies of the problems involved, and the continuity of the current of earlier views here has been maintained. This former trend has persisted not only in psychiatry but it has appeared in neurology which was formed in, and has held to, pronounced morphological conceptions. Dana, Putnam, and Prince, for example, have taken special interest in the physiological and abnormal aspects of mental phenomena. Herter has made the most noteworthy of contributions to the future understanding of mental as well as nervous diseases, by studies of the chemistry of pathological physiology and the disorders of nutrition and metabolism in seeking the fundamental principles of practical therapy. Traceable here, as in general medicine, is the influence of the immensely important work of Chittenden; while this has little or no place in German teachings of neurology and psychiatry, the chemical side of the composition and activity of nervous tissues is receiving attention in England, in recent years, though the special studies of Mott and

Halliburton, which, however, relate distinctly to changes in structural disease. In America, the trend toward functional conceptions of mental pathology became embodied, with a special motive inspiration from general medicine, in the work of the McLean Hospital more than two decades ago. Early in this period, under the added influence of the new teachings of physiological chemistry, the purpose was developed which has led, in the last half decade, to Folin's chemical investigations of disordered metabolism in immediate connection with the clinical study of the physical conditions and treatment of the insane; the parallel development, on both physical and mental lines, of the original purpose there is also finding its prime expression in the recent establishment of another clinical laboratory in which Franz is applying the physiological and experimental methods of the trained physiologist and psychologist. This particular development of the tendency to studies of the physiological aspects of psychiatry has been characterized throughout by its essential purpose of seeking guides for treatment of the physical conditions associated with functional mental disorders.

It appears that the turning-away from the barrenness of histological provings is becoming general; the improvements of the clinical method and psychological experiment are inevitably drawing attention to the closer observation of the individual patient, and to the better study of the minor causes of his mental variations; this means a trend toward physiology. It is a safe prediction that pathological physiology is to be called to render such aid to psychiatry as it is giving in general medicine; and that the extraordinary advances in pathological chemistry will become available in mental diseases.

Such are some of the considerations suggested by a survey of the present aspects of the field of psychiatry. The changing attitude of psychiatry toward psychology is of great significance. These circumstances guide the inquiry into the conditions and causes of the present position of psychiatry.

The Relation of Psychiatry to General Medicine

Psychiatry belongs to general medicine.[1] This view has been presented in the annual reports of the McLean Hospital since 1882;[2] my first statement of it, in the report of that year, was to the effect that the physiological basis of the treatment of the insane lies in the fact that the normal functions of the cerebral organ may be only temporarily disturbed or only partially impaired, whether by transient disorder or pathological change; and the consequent fact that, in most cases, some degree of normal function remains. This principle was stated to be in accordance with the most important gain of modern pathology, the modern conception that "Disease is, for the most part, normal function acting under abnormal conditions."[1]

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[1] Cowles, E., *Advanced Professional Work in Hospitals for the Insane, Am. Jour. of Insanity*, vol. LX, 1898; *The Mechanism of Insanity, ibid.*, vols. XLVI, XLVII, XLVIII, 1889–91; also *The Shattuck Lecture, Neurasthenia and its Mental Symptoms*, 1891, *Bost. Med. and Surg. Jour.*; *Mental Symptoms of Fatigue, Transactions*, N. Y. State Med. Assoc., 1893.

[2] Cf. *Annual Report*, 1882, 1889, *et seq.*

Mental diseases, in their study and treatment, include more than is contained within one branch or department of general medicine by having to deal with the mental effects of pathological conditions of the whole body; psychiatry is not limited especially to the nervous system with its central organ, which has functions of a wholly different and higher nature than those of any other organ. There are functions of the brain other than the common ones of receiving impressions and reacting uniformly upon them like a reflex mechanism; by its mental function it receives impressions, retains and recalls its conscious experiences, selects from and rearranges them, and in new and orderly forms initiates and controls the processes of motor expression. The psychiatrist newly attempting the precise study of mental symptoms is confronted at the outset with the oldest of problems, the relation of mind and body. If he turns to physiology and neurology for light upon the physiological terms, mental and physical, of his problems he meets everywhere such statements as that of Wundt: "In matters psychological the naturalist can only affirm that psychological phenomena run parallel with physiological facts, but that on account of their different natures he has no prospect of ever bridging the gulf between the two." Edinger [2] writes, "We have no idea how it happens that a part of the work done by the nervous system leads to consciousness." Lloyd Morgan[3] offers the following practical conclusion: "One of the difficulties is that of conceiving how mind can act on matter, or matter on mind. . . . Let us at once confess our ignorance of the nature of the intimate relation of the one to the other. But certainly in many cases the observed facts show that, our ignorance notwithstanding, they *are* somehow related. . . . And since we cannot know the nature of the relationship, let us be content to seek for some of its conditions."

The psychiatrist is a physician who should take his point of view in a field even broader than that of general medicine in its largest sense, and not within the narrow limits of any specialism which may seem to include the sphere of mental activities. He has to deal with the physical effects upon the individual of all the influences that act upon him in his environment, and that enter into him from without, or are engendered within, which make for the maintenance or impairment of his vital processes. Such physical influences contributing to conscious experience have their mental effects; the psychiatrist must not only seek to understand the physical changes and effects but he must deal with the patient's consciousness of them; and the more subtle influences that affect the subconscious mental life. The physician must study not alone the influence upon the mind of the body in health and disease, but also the external physical, social, and moral conditions of the environment unfavorable to mental health and growth. It is in association with this broader view of general medicine that, with respect to mental disorder, he must seek explanation on the physical side of the organism, and turn to expert research for such aid as can be given him by the contributing sciences.

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[1] Dr. Gairdner, *Presidential Address, Brit. Med. Psych. Assoc., Jour. Ment. Science*, 1882.

[2] Edinger, L., *Brain Anatomy and Psychology, The Monist*, vol. XI, 1901.

[3] *Relation of Mind to Body, International Quarterly*, vol. VI, 1902.

The field of the medical sciences is as wide as that of biology, which comprehends all the interdependent phenomena of mental and physical life; the abnormal must be referred to the normal. The first recourse of the psychiatrist is to physiology, whose domain is the study of the forces or functions of living matter. There are no symptoms until there are deviations from normal function; without functional activity disease is impossible.[1] On the side of normal life, living substance necessarily presents the conditions of structure, form, and function; these conditions are primary and disease is not necessary to the existence of living substance. Here the general physician finds himself involved in the contention between the sciences of physiology and pathology; the psychiatrist needs first a normal standard in his knowledge of general physiology, and all that he can learn of mental physiology and its relations to its mechanism, structure, and form. Psychology lays open to intimate study the facts of the mental life; on the anatomical side we can know little, and that little explains nothing of the relations between mind and body. It is at this point that the physician must choose his point of view and form his conceptions of fundamental principles. If these are true, they should fit all discovered facts, whether of function or structure, and will lead to advancement of his knowledge; if not true, they lead to conflict and confusion, and obstruct progress. It is necessary to examine the mutual relations of the biological sciences to know their relative value to psychiatry.

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[1] Cf. Orth, J., *Relation of Pathology to Other Sciences*, *Am. Medicine*, vol. IX, 1905. "When there is no functional activity and thus no deviation from normal function there can be no disease." Published while this paper was in manuscript.

The Position of Pathology and its Influence upon Modern Psychiatry

The science of pathology, with the justification of its brilliant achievements, holds itself to be fundamental to the medical sciences. Its elucidation of the phenomena of disease and its results puts it into inseparable relation with life. It claims that its conceptions comprehend all of biology, for on all sides it bears essential relations to the subsidiary biological sciences. Deviations from normal structure and composition of the body, and from the normal functions of its parts, are held to belong to pathology; in this view the study of structural variations in the evolutional and the developmental processes from the normal in primordial and embryonal forms may explain inherited and congenital disease, and, as a part of pathology, throw light upon morphology. Physics and chemistry, as they underlie both function and structure, contribute to the explanation of pathological change, and the disorders of function caused by disease; and pathological physiology and chemistry, whose importance is now receiving growing recognition, are to be regarded as subsidiary to pathology and dependent upon it. In the sphere of general pathology, dealing with function, it finds its duty to be "to correlate symptoms with structural changes and trace the connection between them."

The science of pathology, presenting by its salient aspects such claims to the physician who seeks for light upon the problems of psychiatry, reveals a changing history. The leadership of the pathological-anatomical school in France passing over to Germany culminated in the "cellular pathology" of Virchow, this being founded upon the principle that the cell is the unit of structure and function and that all vital processes are to be referred to the activity of the cells of which the body is composed; they are the "factors of existence." This includes the phenomena of disease and all alterations of the organs and tissues, the principle being that whatever acts upon the cell from without produces a change, either chemical or physical, in the cell structure, and disease is constituted of such changes. These principles became the foundation of the "exact medicine" of the present day. Griesinger first established modern psychiatry upon the exact basis of scientific research and pathological principles, and through Meynert pathological-anatomical teachings were greatly advanced; following them it was in such an environment that the latest schools of psychiatry had their beginnings with an immediate inheritance of its morphological conceptions as the fundamental criteria of scientific truth. Such were the conditions of the inception of the current teachings, based upon a rigid morphology. The German schools of psychiatry became the centres of interest and influence, and their characteristics have already been noted. In the history of the time from Virchow, Griesinger, and Meynert to the present there have been momentous advances in the other biological sciences as well as in pathology and psychiatry. The two latter lines of research are being strongly influenced by the concurrent changes. There are some very recent and significant signs of changing views in psychiatry which possibly betoken the freeing of itself from the too rigid dominance of structural pathology.

The Relation of Pathology to Other Biological Sciences, Especially to Physiology

Physiology, when it declared itself an independent science by breaking away from medicine and establishing its place in the great realm of biology, entered upon a broader field of study of the functional side of life with its complex phenomena in the functions of all living matter. To morphology, as an equally independent science, belongs the study of the structure and form of living matter; it covers the whole field of anatomy in the special forms of zoölogy and botany. But physiology and morphology, which are closely woven together, are both built upon the foundation of the inorganic elements of inanimate matter with its controlling laws of physics and chemistry that govern the forces of inanimate phenomena. All these forces of animate and inanimate nature are bound together; from a biological point of view we do not know living matter without both form and function.

On the part of the physician the inquiry at this point is as to the true relations of pathology to the other biological sciences in medicine. The scientific foundation of pathology, the development of its work in the other sciences which it necessarily involves, support its claim to an equal place in biology with the other natural sciences.

Prof. Orth, in an address at Kassel in 1903, described pathology as consisting of two branches, anatomy and physiology. Although the great Virchow remained a pure pathological anatomist, he contemplated the beginning of pathological physiology as the culmination of his endeavors; "one of his favorite themes was the establishment of pathological physiology, a subject which, to his mind, was the foundation of scientific medicine, and therefore of medicine as a whole." Practical medicine, according to Virchow, is coextensive with pathological physiology; this is founded on pathological anatomy, clinical observations, experimental researches; its problem is the determination and investigation of bodily processes under abnormal conditions, of illness and its symptoms. Virchow's experimental investigations to clear up morphological characteristics of disease go only to the beginning, and Prof. Orth urged that better attention should be given to physiological methods for the determination and interpretation of functional disorders in the unhealthy organ; yet pathological morphology must remain the unchangeable groundwork of all medical knowledge and thought; its most important function is its purpose for the upbuilding of pathological physiology, for the understanding of the living processes and their disturbances in the sick body.

Bacteriology in its marvelous progress leads investigation directly into the field of pathological physiology, and finds explanations in the normal physical and chemical reactions that belong to the normal cell physiology. Pathology, taking bacteriology into its special province, is engaged in the study of problems relating to the nature of disease. General physiology has shown that the physico-chemical reactions in living substances are fundamental and essential factors in the production of vital phenomena; it finds, in its investigation of the component elements of cell-substance, that in physiological chemistry is its chief aid in the explanation of vital activity and its disorders. Herter [1] reviews our present knowledge of the chemical defenses of the organism against disease; it serves to emphasize the varied chemical activities of the cells, and to render more intelligible the phenomena of diseases that result from modifications or failure of these cellular functions. He says: "Modern pathology has made us familiar with the conception that disease is generally the expression of a reaction on the part of the cell to injurious influences. The only rational conception of the ability of the human body to defend itself against disease by means of chemical agencies is that these defenses ultimately reside in the cells themselves. Many of the phenomena of disease are caused by the modification of function that occurs during the action of the cell in resisting injurious influences." Ernst [2] has shown that, notwithstanding the great obscurity of the subject and the somewhat conflicting theories, the point is maintained that in all reactions the cell activity intervenes at some stage of the production of immunity; and that most probably the reactions that occur are closely related to these that go on under the ordinary conditions of tissue metabolism. These considerations are consistent with the fundamental doctrine of cell physiology and pathology.

It appears from a brief survey of the history of pathology that when at first it was part of anatomy, it was then preëminently morphological, and that this characteristic motive still prevails to a large degree. After it became independent, pathology concerned itself especially with deviations from the normal anatomical standard. It developed new relations with the other biological sciences as they attained existence, and like morphological problems arose in connection with them. There was mutual receiving and giving of aid, but anatomy was the parent science and the study of the concrete facts of structure being easier than ever-changing function, morphological conceptions have always kept in advance and pathology has held them to be essential in giving finality to its explanations and proofs. But with the slowing of progress, as normal and pathological histology has approached the frontiers of present attainable knowledge, much of speculative theory has arisen in the endeavor to prove apparent and conjectural realities of structure by reference to the facts of physiological activity. The history of pathology reveals evidence in support of the conclusion that, from the beginning, the science of pathology has needed first the data of normal form and function in order to study their deviations; also pathology has been steadily tending to the finding of its ultimate dependence upon physiology. Aside from the results called disease from actual traumatism of cell bodies caused by extrinsic agencies there must be many transient conditions of intracellular rearrangements or molecular disorder, beginning with functional and defensive reactions, long before there can be any ascertainable structural findings. Such molecular changes, beyond the ken of the microscopist, might be assumed to be structural in fact; but the ultimate problem of the search for explaining principles thus tends to become a physico-chemical one. The facts of cell functions should hold an important place in the study of the varying agencies and influences of cell stimulation in the production of symptoms. The relation to physiology of the morphological side of pathology is especially instructive.

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[1] Herter, C. A., *Chemical Pathology*, 1902.

[2] Ernst, H. C., *Modern Theories of Bacterial Immunity*, 1903.

The Relation of Morphology, Normal and Pathological, to Physiology

Morphology presents considerations of the highest importance which require special notice in this examination of the mutual relations of the biological sciences. It is granted that pathology, on the morphological side, is inconceivable without normal anatomy as its basis. Pathological anatomy, being dependent on normal anatomy, belongs to the science of morphology. This science, with its great subdivision of embryology, has attained splendid achievements; in the course of its advancement in many specialized lines of investigation in plant and animal life, it has enjoyed the advantage of being able to study the problems of evolution and development in many quickly succeeding generations of vital forms. The scope of its observations has extended farther than from the point of view of medicine, and is reaching conclusions that may yet illuminate some of the dark places of psychiatry. The history of morphology has a special significance in its development cotemporary with other biological sciences; the changes in its course suggest a law of progress in scientific research that has operated in other fields. After the emergence of morphology, and of physiology, from the keeping of anatomy, the two new sciences entered upon equal domains in the realm of biology. Morphology asserted the independence of the science of form and structure from that of function; the doctrine was that form persists and function varies. It was characterized by the conception of a fixity of types, a rigid adherence to the study of mature forms which it labored to arrange in a perfected and systematic classification. With the breaking-away from these rigid conceptions, during the last fifty years, the course of progress was in the study of the problems of evolution; leading through the investigations concerning the origin of species, it has come to the recognition of the supreme importance of the problems involved in the development of the individual, and of the biological laws that govern it; and the wide range of variations that may be produced in members of a given species. So in medicine, instead of clinical types, the differentiations of disease are becoming genetic and developmental in character.

In the morphology of plant and animal life it is agreed on both sides that they are subject to the same laws; in both plants and animals there are identical processes which are consistent with the significance of the cell doctrine as being fundamental to morphology. In the close relation of form and function the modern conception is that the structural characters of which an individual organism is made up correspond to its functional characters; form characteristics cannot be understood without considering the function characteristics. Physiological characteristics are transmissible in the same way as the morphological. The study of physiological cytology and embryology is revealing the mechanism of the transmission of qualities; with the aid of the experimental methods in the production of variations in both form and function, there is great progress in the understanding of the laws of descent and inheritance. The close relation of physiological and morphological characteristics proves that the problems of form and structure are also physiological problems. Physiological processes are influenced and often controlled by the conditions of the environment both internal and external; and it is shown that mental as well as physiological characteristics are inherited under the same laws. These brief references to the data of morphology serve here to indicate the trend of progress in this science; it points to the conclusion that influences which stimulate functional activity play an essential part in determining the processes of development and the resulting structural forms. The demonstrations of the dominance of the sensory over the motor side of the nervous mechanism is consistent with the fact that all movements are primarily a response to sensory impressions and are performed under their guidance. It follows from the teachings of Hughlings Jackson that cell-groups are thus formed by a process of education. All motor phenomena being responsive reactions to stimuli applied to the neuro-muscular mechanisms, the laws of use and habit influence functional activity and growth. The unity of all these sciences is also shown. Physiology and morphology have to do with interdependent manifestations of organic existence; there can be no disease until there is first normal life with whose physical sequels pathology has to deal. Inasmuch as the whole science of pathology must refer all its material to normal standards, both on the functional and the morphological side, a like freedom belongs to the minor province of mental pathology; psychiatry is at least justified in seeking directly its immediate explanations in the hopeful though neglected field of function.

The Pathological Conceptions of Psychiatry stated in Terms implying Morphological Ideas

In such a survey as this, of so complex a subject, certain difficulties have appeared concerning special aspects of current effort, in the field of the psychiatrist's labors. Allusion has been made to the remarkable fact of the disharmony between mental physiology and mental pathology. There are signs of the coming of better coöperation, but so far the general fact is that the psychiatrist borrows from psychology what seems fitting with his pathological conceptions, and applies some of its psycho-physical methods; at the same time he hesitates to use the data and even the terminology offered by expert investigators in mental physiology. The importance of care in the use of descriptive words has been mentioned; an inquiry like this draws special attention to this subject and some extraordinary facts are revealed that should receive further notice.

First among these may be mentioned the use of the word physiological; its frequent infelicitous employment by both pathologists and psychologists themselves emphasizes the width and depth of the traditional gulf between mind and body. The distinction is commonly made between *psychical* phenomena and *physiological* phenomena and the designations "mental side" and "physiological side" are used to make the same contrast. Mental phenomena are themselves physiological, but the usage implies a distinct psychical element as an extra-physiological epiphenomenon, when such a meaning is not intended, and is therefore misleading. The mind event and the brain event are both physiological.

More remarkable examples of doubtful usage, universal in medical literature, and with far-reaching effects, are shown in the words "disease-form," "disease-entity," "disease-process," and "pathological process," which have already been mentioned. These words still suggest old meanings now wholly obsolete; this is so obvious that when thoughtful writers use such words "for convenience," the explanation is not infrequently made that it is not intended to imply that disease is a malign entity which invades the living body and works its evil course. Yet, as usage sanctions it, writers continue to employ the framework of words which would once have expressed the ancient parasitic personification of disease. While, in the science of pathology, this extreme conception is corrected by explanation, such words in their modern usage still embody and positively convey the sense of an underlying morphological counterpart of the symptom-complex that runs its course of progressive degeneration as a disease and reveals the terminal changes in post-mortem findings. To speak of all disease in terms used in these senses is to emphasize structural conceptions of pathology, and thus to impede the progress of the reform which is clearly seeking to give adequate attention to functional conceptions in place of the dominating demand for mature types and forms and classifications.

It would be interesting to follow out the history of the usage of these verbal embodiments of whole theories. Perhaps a reference to main points will be enough to indicate the purport of these observations. First, as to the nature of disease, it cannot be correctly conceived as a state of disordered activity or disorder of a process in an *active* sense; there is a condition produced by a defensive contest between the forces of the living cell and the harmful agencies; it is not a state of perturbed activity but the result of it in diseased organs or tissues. The causes of disease are extraneous and unnecessary to cell-life, which can exist without disease. The only true *process* in living organisms is the physiological, or life-process; the forces that cause the reactions called vital phenomena are inherent and are governed by the uniform laws of an invariable order of nature; like effects result from like causes and conditions, and the life-process presents the attributes of uniformity and continuity controlled by the laws of descent. Reproduction is an original property of living matter and life is continuous, and death is not due to such a property; this is a proposition in which there would be a general agreement with Weissmann. Roger [1] reduces the conception of death to the formula: "Death is the result of an arrest of cellular nutrition; whatever the multiple proceedings are that are called into play, the final result is always the same."

A "disease-process" or "pathological process" cannot be conceived as comparable with the physiological process; the causes of disease being extraneous to normal cell-life are accidental, multiple, discontinuous, without uniformity. It is consistent with this that even in the problem of tumor growths there are some essential explaining facts; whatever of the various theories may be employed to account for them, they are not in dwelling entities, but depend for their existence upon the inherent vitality of the parent organism acting under abnormal conditions. When the organism dies the new growth dies; there can be no disease without prior normal life.

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[1] Roger, G. H., *Introduction to the Study of Medicine, Trans.*, 1901.

When applied to functional disorders, the assumption of a necessary correlation between a "disease-form" and an underlying structural "disease-process" goes beyond the province of morphological pathology; it involves the intracellular changes of physiological chemistry. It is obstructive of a true conception of the wide variations of function that belong to molecular nutritive and metabolic changes due to variations in condition, irritability, intensity of stimulus, etc., though affecting the same physico-chemical operations by the same agencies. But an authoritative insistence upon the "disease-form" and "disease-process" ideas, with respect to all psychoses, has undoubtedly tended to distract attention from a free consideration of functional conceptions of mental pathology. These and kindred forms of words, with their distinctly morphological stamp, show the character, in some degree, of changing conceptions of pathology. They are kept in use by their convenience; and they appear to be in harmony with certain accepted theories and doctrines concerning the nature of disease and death, and their relation to life. The influence of these doctrines is so great as to require examination here.

The difficulty of determining a sharp limit between life and death has been stated by Verworn:[1] there is no definite time at which life ceases and death begins in a complex organism, for one set of cell-complexes may survive another for a long time; but "there is a gradual passage from normal life to complete death which frequently begins to be noticeable during the course of a disease. Death is developed out of life." "Thus death does not come to the cell immediately, but is the end-result of a long series of processes which begin with an irreparable injury to the normal body, and lead by degrees to a complete cessation of all vital phenomena." It is reasoned that "life and death are only the two end-results of a long series of changes which run their course successively in the organism;" also that "death undergoes a development; normal life upon the one hand and death upon the other are merely the remote end-stages in this development, and are united to one another by an uninterrupted series of intermediate degrees." This transition from life to death is termed *necrobiosis*, a word introduced into pathology by Virchow and Schultz; it is understood to mean, according to Verworn, "those processes that, beginning with an incurable lesion of the normal life, lead slowly or rapidly to unavoidable death."

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[1] Verworn, M., *General Physiology*, *Trans*., 1899.

Thus the principle of necrobiosis is to be studied in the cell as well as its vital phenomena; and it is held to apply also to the death of compound organisms. By an extension of this conception it explains the condition of natural death in old age, which thus appears to be physiological. Senile atrophy, which leads finally to death from the feebleness of old age, is to be regarded as simply the end-result of a long developmental series; death in old age is the natural end of an unbroken development and its causes exist in the living organism itself. Life itself never becomes extinct, but there is a continuity in its descent; yet living substance itself, in the form of bodies, is continually dying.

Compare with the foregoing the views presented by Gowers [1] in regard to "diseases from defect of life" to which he gives the designation "abiotrophy" to distinguish a newly differentiated clinical group of conditions and symptoms; he acknowledges Mott's cotemporary recognition of these conditions. The conception is that of "a degeneration or decay in consequence of a defect of vital endurance;" it indicates a failure of life-processes due to defective vitality which seems to be inherent. It is recognized that many degenerative diseases of the nervous system are a result of such defect. The idea is expressed by Mott: [2] "The neurones of a particular system die prematurely, owing to an inherited or acquired want of durability, and the regressive process of decay may be looked upon as a nutritional failure on the part of the same cells to maintain that metabolic equilibrium essential and correlative to functional activity." Every nerve-cell of the human body is conceived to be "endowed with a specific durability whereby in the health-perfect organism every neurone possesses an equally adjusted vital energy." This is a statement of one of the two ways in which the regressive process occurs, the other being "the metamorphosis incidental to old age manifested by a gradual and general enfeeblement of the functions of the whole nervous system." "In contradistinction to this normal senile decay are the premature pathological processes of decay attacking groups, systems, or communities of neurones subserving special functions." "The process may be regarded as the inverse of development;" in harmony with these views Hughlings Jackson is quoted in regard to the helpfulness of considering diseases of the nervous system "as reversals of evolution, that is, as dissolution." Mott conceives that the process of primary degeneration is, morphologically, an evolutional reversal commencing in the structures latest developed.

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[1] Gowers, W. R., *Abiotrophy, Lancet*, 1902.

[2] Mott, F. W., *The Degeneration of the Neurones, Croonian Lectures*, 1900.

In the extensive literature concerning the life-processes and their failure in disease and senility other diverging views may be cited, but the purpose here is only to indicate certain ideas and reasonings that bear upon the pathological conceptions with which psychiatry has had to labor. With respect to physiological old age ending in natural death the contending view is that the decline of life manifests the summation of the effects of external injuries, the damage of wear and waste, and is not something different and apart from disease. It is to be noted in the doctrine of necrobiosis that the idea of a "disease-entity," with its course and process parallel and antagonistic to the life-process, is avoided by conceiving life or the life-principle as the sole producer of two series of developmental processes, one of which leads to its end-result in the existence of normal being; this life-process is also conceived as turning against itself in another process of producing a series of decrements that reaches to the end-result of non-existence. One result must exclude the other, and we admit that death is the common goal; the life of every living thing ends in death and there is only one end-result, — death is developed out of life. But by shifting the position to the larger view the attempt is to set up a dual conception of two processes, equal, parallel, antagonistic, yet conjoined. The truth is that the whole of life comprehends all living nature; the individual parts that bloom, fructify, and perish, and the fragments chipped and sloughed off from the great embodiment of life in matter, are always dying or dead, but the one chief process of life goes on, and we say that life is developed out of death. The minor casualties of injury and disease represent the chance encounters of living substance in its struggle for existence with the discontinuous opposing forces of the world of living and material things. Living substance dies, but life is immortal. We may describe, in such figures of speech, the dual developmental processes with their contrasting end-results.

The paradox of the "processes" appears also in the application of the doctrine of abiotrophy which, of itself, helps to make clearer the terms of the problem by the conception of a failure of nutritional energy with a consequent limitation of the durability of the organism and of the length of life. In applying this doctrine to certain pathological changes it is said that the overgrowth of interstitial neuroglial tissue, when the nerve elements decay, is in consequence of the fact that the two elements have "a common but inverse vitality;" when the nutritional energy fails to maintain the growth of both, the more highly specialized tissue ceases to live, while the less specialized tends to overgrow with the tendency of the former to decay. It is explained that these "tendencies are in the opposite direction, but they seem to be coincident results of the same vital condition."

In the many well-known conditions of constitutional weakness and instability it is easy to understand the nutritional failure to develop normal growth and efficiency of function, or to maintain them, and the consequent recession of the developmental processes, even to the cessation of life. The doctrine of dissolution as characterizing the many conditions of such recessions is clearly consistent. When biological conceptions are invoked, it is also easy to comprehend the general principles of development whereby, through physiological reactions of the organism, there are adaptations and modifications of characters due to changes of environment and favorable to life and health; it is intelligible that through use higher types of characters may be produced, or through disuse recessions to more primitive types, under the causative influences of the environment, and all this may be within the physiological limits of the organism as expressions of the processes of life. In the domain of biology it is, no doubt, helpful for descriptive purposes to conceive of the developmental forces as acting in an inverse direction, producing the effects of reversals and regressions. But when this latter conception is applied to pathological conditions, it is in harmony with our prevailing modes of thought in medicine that there is conceived to be an attack, as of some harmful agency, upon the living organism; a pathological process of degeneration is supposed to ensue which is a regressive process of decay, and this implies its active going backward against the normal tendency of the nutritional energy to maintain life and growth. As a further explaining principle the conditions of acquired or inherited defect are conceived, and a process of degeneration of which "heredity" is the motive force; thus the developmental forces turn against themselves, and, working in the inverse direction, produce decay. It is the all-pervading disposition to seek an immediate cause for every effect, and it is easy to describe agencies and processes. When the stamp of "degeneracy" is fixed upon a fated organism we commonly think of its possessor as a "degenerate" descending to inevitable doom.

Is it not evident that there is a misleading ambiguity in the prevailing usage of the conception of "processes"? It is necessary to the notion of a process that there is a passing over of one set of phenomena into another, and this constitutes a change.[1] A "process" is constituted of a series of such changes when one stage or aspect of the process necessarily succeeds upon another. The action of a causative force or stimulus is essential to the change, as in the biological processes. The requirements of the conception of two coincident processes appear in the principle of the psychophysical parallelism in the relation of mind and body. It being the general fact that certain changes in those brain- and nerve-processes with which consciousness is associated are always accompanied by changes in consciousness, and the converse being true also, then certain other scientific principles are involved: (1) the principle of *equal continuity*, with no breaks in either series of changes, — if one series is continuous the other must be continuous also; (2) the principle of *uniformity*, when certain phenomena in each series in brain-process and conscious state are essentially associated, then the concomitance of those terms may be looked for on all other occasions; (3) the principle must be a *universal* one, — whenever we find a series of phenomena in either of the parallel trains of events the principle of parallelism has its application. Structure and function must exist before there can be any disease; the phenomena of life represent the supreme process in animate nature; the phenomena of disease and degeneration appear as the results of discontinuous interferences with the life-processes in which "normal function is acting under abnormal conditions;" the assumption of a "disease-process," or of a "pathological process" in the same sense, fails to meet the essential requirements of a "process," — it is certainly not comparable with the life-process. If we must speak, for convenience, of "pathological process" and "degenerative process," the terms should be used only in a very narrow sense of comparatively transient interferences, or in the sense of referring to normal function acting pathologically.[1]

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[1] Baldwin, J. M., *Development and Evolution*, 1902.

To the inquiring mind the contradictory presentations of these matters is confusing and creates difficulty. The subjects are, in their nature, complex, and our knowledge is limited, but much ambiguity is undoubtedly due to the lack of precision in the statement of the terms of the problems. One of the most common obstacles to clear thinking appears to arise out of the fact that for every predicate implying action we have to think of an actor, or causative agency, and our minds habitually conceive of some form of personification of such an agent as possessing motor and motive attributes. Thus we think of life and death, and artists picture them, in human forms; we are prone to dualistic conceptions and the mind delights in such paradoxical phrases as, there can be no death without life; no disease without health; no evil without good. The use of the active predicate abbreviates expression and enlivens speech. Professor Sanford,[1] discussing the influence of physics on psychology, notes the fact that, as the result of man's long primitive practice, his habits of thought are objective, and the language he uses is saturated with physical connotations and metaphors. It is not easy for even the best of us, he says, to keep clear of this inveterate physical-mindedness and the subtle suggestions of language; we help out our thinking by material figures and feel a sort of dumb compulsion to make our psychological theories accord with physical requirements. Ebbinghaus is quoted as describing the older psychology as distinctly "mechanistic," many analogies from familiar material processes being used in the exposition of mental phenomena. In regard to essentials, Professor Sanford thinks it may be said that psychology has outgrown this method. But turning to our own field of the medical sciences, the ruling tendency of our thought and language leads to the conceptions of "disease" and "process," for example, in terms implying immediate causative agents. The familiar conceptions of a process of anabolism and a contending process of katabolism in the cell are treated as the analogues of the life-process and death-process. The analogy is extended to include in this conception the fact that in the whole compound organism the anabolic processes overbalance the katabolic till middle life, when the two processes are more nearly in equilibrium, and that thereafter katabolism predominates more and more in the normal decline of old age. It is held that in the broadest sense the process of senescence begins with the beginning of life in a progressive diminution of the power of growth; and with the progressive waning of the vital powers the leading somatic changes accompanying old age are atrophic and degenerative. The same conception concerning the anabolic and katabolic processes is equally legitimate concerning the idea that an inherent tendency to degeneration is transmissible; the inherited constitutional weakness and diminution of vitality may be interpreted as belonging to the series of changes which imply a process of dying continuing through several generations.

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[1] The writer's views of the inadequacy and misleading influence of the "disease-process" conception as a question in psychiatry was first presented to the American Medico-Psychological Association at its meeting in Washington in 1902, in an unpublished paper on the principles of mental pathology and the nature of mental symptoms.

There appears through all these reasonings the prevailing method of thinking in terms of "processes." The inquirer is moved to ask whether the normal processes of anabolism and katabolism are not both essential to the maintenance of a health-perfect cell and both, therefore, parts of the normal life-process? We do not think of the most healthily active cell as one most vigorously dying. If we consider the physico-chemical changes in the cell inclusively as a process of metabolism, it is consistent to think of the normal building-up and breaking-down of complex compounds in growth, work, and repair as harmonious, and not antagonistic, operations.

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[1] Sanford, E. C., *Psychology and Physics*, *The Psych. Rev.*, vol. x, 1903.

Hering separates assimilation as only a qualitative chemical change from growth as quantitative, and in like manner dissimilation from atrophy. As to the transformations in the cells and the overwhelming number of substances excreted from them, little is known of the processes by which these are derived; but many products are formed in both the ascending and descending portions of the metabolic series. Disordered and imperfect adjustments of the molecular arrangements of living substance may affect and arrest both anabolism and katabolism; defect of the latter and not its predominance can be conceived as a cause of the death of the cell.

In physiological theory the distinction is made between death of the tissues and somatic death: in the former, it is reasoned that constantly throughout life the molecules of living matter are being disintegrated and whole cells die and are cast away, — and that life and death are concomitant; in the latter, death occurs when one or more of the organic functions is so disturbed that the harmonious exercise of all the functions becomes impossible. This distinction has been referred to, and further inquiries are suggested here. In respect to the death of the tissues, the "unit cell," being an organism of high complexity as to its structure and function, and its life-process, is not failure of this life-process of the coöperative adjustments within the cell truly analogous to the failure of life, or somatic death, in the whole compound organism? In this connection the question again arises as to the concomitance of the processes of life and death, — the latter being theoretically analogous to the constant disintegration of living matter. Hering's idea that assimilation and dissimilation are distinctly separate from growth and atrophy permits the former to be regarded as one intimately combined and normal metabolic process in a working cell, having no theoretical significance except as wholly contributing to the maintenance of the function of a health-perfect cell. The daily shrinkage of the working and fatigued cell may be regularly made up by rest and nutrition; this is not atrophy, either simple or degenerative, for the continuity of cell-life may be unimpaired and only the labile molecular inclusions be changed by normal use which promotes the health of the cell. On the other hand, the function of growth, being of a more primitive type, would appear to contain the explaining principle of the life-process as contrasted with the work-process. Consistent with this appears to be the sharp differentiation by Adami between cells which have the habit of growth and those which have the habit of work; these two functions cannot be exercised by the same cell at the same time, and a normal working cell may revert to the type of a vegetative cell. This implies that cells of the primitive type having only the function of growth, their "work" (in the common usage of the word) is without external manifestations of energy; but that the function of work, which is the power to store potential energy within and to produce kinetic energy in external work, belongs to the highly specialized cell as an acquired character which it may lose. This being true we may understand that assimilation and dissimilation, in the limited sense employed by Hering, constitute a special kind of inclusive metabolic process different from the molecular changes, perhaps less complex, productive only of growth. It is not conclusive that katabolism typically represents destruction of life, though it means changes of substance in which life exists. These considerations suggest questions that are not in harmony with the generally accepted theory of life and death as concomitant processes based upon an assumed analogy to the physiological processes of the healthy living cell.

This inquiry is intended only to consider some examples of current theories with the question whether they can be resolved into more simple conceptions. The life-process being conceived as the one supreme "process" in living organisms, this implies its maintenance by causative forces; assuming each individual to be endowed with a given vital durability, determined by antecedent conditions and subject to modifications due to favoring or adverse influences, the life-process reaches its possible attainments and finally fails in the struggle for existence. Injury, interference with normal function, overuse and disuse, disease, and the causes of the changes of senility present alike adverse influences which the organism fails to overcome. We must speak of disease and use its meaning as referring to results in diseased parts, organs, or tissues; and we may commonly think of the word as implying a combination of disorders of functional activities which may or may not be associated with ascertainable structural changes. But it should be remembered that we are thinking of a patient and not a "disease." There is no disease-process; no causative forces exist in nature that induce and carry on processes of degeneration and decay; gradual failure is the summation of the failures of community work due to the complexity of the organism, each organ being subject to the harmful influences of the functional failure of other members of the community. There may be deterioration of function, and degeneration of structure in the sense of failure to maintain it; there may be also regressions or rather recessions of results, but no active pathological "process" of going backward in the structural reductions called "degenerative." These considerations do not support the idea of a "physiological old age," based upon the conception of a normal process of degeneration or decay as though the results of senile conditions in structural changes are different from disease. This doctrine of natural decay and death makes great trouble in dealing with senile conditions in medico-legal cases; and in like cases concerning degeneracy in earlier life the most contradictory and confusing notions prevail. They are not in harmony with practical experience. This is largely due to the adoption in psychiatry of generalizations in regard to heredity not yet warranted by the science of biology. The morphological ideas in the prevailing pathological conceptions, and the descriptive terms employed, have undoubtedly obstructed the progress of psychiatry. From all such preconceptions the psychiatrist should be wholly emancipated.

A functional conception of pathology is not in conflict with a pathological conception in the sense of the long-used distinction between functional and organic diseases. The objection to this is not lessened, but the fault is not with function. Life and the science of physiology are first; function and all that pertains to it are primary facts of the activities of normal life. Much disharmony in the conceptions of pathology has been due to the setting-up of ideas of "organic diseases" as the chief factors in pathology, and the minimizing of function as worthy of serious scientific consideration. Our conceptions of function are uncomplicated as relating simply to the modes of action of the several parts of the organism; but we must think of organic disease in two ways, of changes of structure in results, and of changes of action in "process." The functional factors are necessary to organic disease and their distinction and true relation should be discovered in their combination. The organic changes of disease are the sequels of interferences with the prime process of normal life.

Physiology and its Relation to Psychology

Physiology acknowledges its debt to Johannes Müller, who mastered the two great sciences, morphology and physiology, and was a teacher of pathology. He took an active interest in psychology, regarding physiology by empirical methods as essential to advancement. After Müller's death, nearly fifty years ago, the fields of his scientific work were divided by the specializations through which the present marvelous advancement has been gained. Physiological chemistry became independent of physiology; and physiological psychology developed on the lines of psycho-physical experiment. It was then that mental physiology should have made its union with mental pathology. It is easy to see that psychology tried to accomplish this by its attempts to find a morphological basis for its investigations through the experimental method, but the field for this was limited. Psychiatry under like limitations, by its morphological attitude, met the invitations of psychology with inherited distrust of a functional pathology; psychology was turned upon itself, and also, much of its own choice, sought and found open ways back into the attractive regions of the investigation of psychical function and philosophy. The later phase of psychiatrical interest in experimentation has been mentioned, and is full of promise, but such movements require years of time. The method of exhaustive study of the clinical expression of psychical reactions through speech and behavior, and the use of experimental tests which bring out individual characteristics and their variations, are gaining a share, which must increase, of the attention and interest heretofore centred in the pathological laboratory. This is a new and definite revelation of a tendency toward the study of a functional conception of pathology in psychiatry.

Psychology is still kept apart, however, from the practical study of mental pathology; this is probably, in part, its own fault; although some students of psychology have shown the requisite interest, there is a lamentable want of opportunity. What would really be the most promising interest in psychiatry should be found in the establishment, in hospitals for the insane, of true experimental psychology, with physiological methods applied clinically, according to the principle of using instruments of precision in other clinical work.[1] The observer of these clinical manifestations trained both as a psychologist and physiologist would find many new variations of phenomena not seen in the normal subject. A hospital for the treatment of mental disorders is a laboratory of itself where nature makes experiments in the excitation, suppression, and combination of naturally correlated psychical and physical reactions, giving many clearer displays of their nature, both by their intensification and absence.

Mental diseases are peculiarly and essentially constituted of mental symptoms; the study of their phenomena must refer them to mental physiology, for the laws governing vital phenomena under abnormal conditions are not different from those of normal life. The study of mental physiology under pathological conditions should be helpful for both psychology and psychiatry.

This inquiry being assumed to be free from all preconceptions as to the true nature and place of mental pathology, and as to forms and names of mental diseases, it may be turned to an examination of the relations of psychology, or mental physiology, to all of the associated reactions of the physical organism. This is the necessary basis of pathological physiology for psychiatry. Approaching the subject newly from this point of view the physician should seek to inform himself concerning at least the immediate facts of mental function and the accepted postulates of psychology. But in preparation for such a study it should be recognized that mental physiology is included in general physiology as concerning a part of the vital activities of the living organism; also that certain general modes of action in the body always have a part in mental function. Some of the symptom-factors of mental disorder have their genesis in conditions that affect primarily other parts of the organism than the brain. General physiology therefore claims the attention of the psychiatrist to certain essential principles whose importance can only be indicated here by mentioning some of those of immediate interest; the purpose is to present some of the physiological reasons for the proposition that the problem of psychiatry lies in the functional psychoses.

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[1] For an account of the beginning of the present laboratory methods, both psychological and chemical, at the McLean Hospital in 1889, see *Les Laboratoires de Psychologie en Amérique*, by E. B. Delabarre, *L'Année Psychologique*, 1895; also *Laboratory of the McLean Hospital*, by G. Stanley Hall, *Am. Jour. Insanity*, 1895. The subsequent development of the pathological laboratory and the clinical methods, — of the laboratory for pathological chemistry in 1900. — and of that for pathological physiology and psychological experiment in 1904, constitute a true psychiatrical clinic of a special character, designed from the outset for the investigation of the functional conditions of mental disorder.

References to Physiological Principles

A distinctive feature of modern biology is the fundamental conception of a living body as a physical mechanism (Huxley); underlying all the phenomena of the animal organism is the reflex action of the nervous system, and physiologists generally agree to consider every action as aroused by some cause or stimulus (Sedgwick); under the biological conception man is an organism for reacting on impressions (James). The nervous and mental mechanisms being regarded as constituted of three minor ones, their action appears in a sensory, — a central or transformation, — and a motor process; in the central process part of the work done by the nervous system leads to consciousness; the response to a stimulus may be a muscular contraction, a secretion in a gland, a vascular change, or even a trophic or metabolic influence, — all pertaining to the centrifugal system. While reflex action is not conscious action, one may be conscious of the act, and in many cases conscious changes precede, accompany, or occasion the change. The most important reflex of all is commonly ignored, viz., that which provides for the constant readjustment of the parts of the system to each other, by virtue of which the entire mechanism is receptive even to minimal stimuli. This may be termed the *neuro-equilibrium reflex.* The tone of the nervous system is this wonderfully complex adjustment of inhibition and stimulation. Every metabolic process in all the nerve-cells exerts its influence on the entire nervous system. One of the most remarkable reflex associations is that between vaso-motor alterations and the seat of the emotions, which are thus intimately involved with the viscera and vessels in their minute connection with the sympathetic system. This association has a most important influence in the mental sphere, though beyond this fact little is yet known of the physiological basis of these reactions.[1]

The intimate connection of mental states and the physical reactions of the whole body is well recognized by both physiologists and psychologists; it is of fundamental importance in psychiatry. Lombard[2] describes the cells of the central nervous system, during waking hours, as continually under the influence of a shower of weak nervous impulses, coming from the sensory organs all over the body; moreover, activity of brain-cells, especially emotional forms of activity, leads to an overflow of nervous impulses to the spinal cord and an increased irritability, or, if stronger, excitation of motor nerve-cells. There is a constant inflow from the environment of a vast number of excitations ordinarily disregarded by the mind but all the time influencing the nerve-cells; the effect of this multitude of afferent stimuli, in spite of their feebleness, is to cause the motor cells continually to send delicate motor stimuli to the muscles and to keep them in the state of slight but continued contraction or tension of *muscle-tonus.* In these mechanisms is the seat of the kinesthetic sensations and the functional alterations that play so essential a part in contributing to the well-known symptom-factors of the "sense of effort" and "inadequacy," and motor "retardation" and "excitation."

Some of the physiologists have given much study to the relation of mental and physical states. Sherrington's[3] discussion of common and organic sensation and the contributing cutaneous sensations has an extraordinary interest for psychiatry. Common sensation is understood to mean that sum of sensations referred, not to external agents but to the processes of the animal body, and these sensations possess strong affective tone. Total common sensation is the result of many component sensations, and those that arise in internal organs and viscera contribute a great deal to the total sum. Affective tone is the constant accompaniment of sensation; every form of common sensation is based on perception of an altered condition of the body itself. In connection with this comes the fact that all forms of common sensation present significantly preëminent attributes of physical pleasure or physical pain; and all are linked closely to emotion.

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[1] Cf. Baldwin's *Dict. of Philosophy and Psychology.*

[2] Lombard, W. P., *The General Physiology of Muscle and Nerve, Am. Text-Book of Phys.*, vol. II, p. 143.

[3] Sherrington, C. S., *Cutaneous Sensations*, Schafer's *Text-Book of Physiology*, vol. II, p. 969, *et seq.*

The elaborate researches of many observers in recent years concerning the nature of the muscular sense, the senses of touch, pain, and temperature, and their special mechanisms, strengthen the common fact that their sum contributes to the effects upon mental feeling-tone. They are in their nature productive in part of the organic sensations. Ribot [1] has studied, more than any one else, the psychology of the emotions and the logic of their mental and physical reactions; he describes the presentations in the conscious mind of organic sense as constituting a vast aggregate of impressions arising from within the organism and continually flowing towards the superior nervous system; it is this region of subject consciousness that gives the consciousness of being, — the sense of personality. The sensations from the special senses are intermittent, of high intensity, and small in volume compared with the voluminous though faint, continuous, and all-pervading commotion produced by the organic sensations. These are intense enough, however, to be susceptible in health of psychical interpretation as a sense of well-being; from their disorders and intensification comes the sense of ill-being. These are the long recognized changes of coenesthesia. Professor James has shown the intimate relation of the emotional tone to bodily states; and Professor Ladd makes clear the usefulness to psychiatry of a study of the affections and emotions in their relations to the train of ideas, and to the different bodily organs; also the reflex effect of the changes in these organs upon both the feelings and the ideas.

Underlying all these physiological phenomena of the living organism is the primary attribute of irritability. All the functional phenomena being influenced, within normal limits, by changes of irritability in the central, peripheral, sensory, and motor mechanisms, and these changes being dependent upon the processes of nutrition and metabolism, and upon conditions of use and disuse, rest and fatigue, etc., the alterations of functional efficiency in the associated reactions of mind and body make the study of cellular physiology imperative for psychiatry. Some of the most commonly observed and characteristic symptoms in mental diseases may be referred to such functional disorders in the physical organism.

Physiology and its Relation to Psychology, continued

The healthy organism being fully constituted in structure and function for its work, when put in use begins immediately to be subject to modes of action which are the effects of its own activities; in other words the living organism acquires functional characteristics as the immediate effects of use. Some of the common physiological laws have a special importance here because they govern the work of the physical mechanism and therefore of all correlated mental reactions, not only in health but in disease, as long as any functional activity continues.

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[1] Ribot, Th., *Diseases of the Personality, and the Psychology of the Emotions.*

(1) *Association* and *Habit* are fundamental in mental life; in respect to the association of ideas it is not the ideas that associate but the elementary processes of which the ideas are composed; on the physical side the law reduces to the law of habit (Titchener). Memory is an associative process; mental reactions (including perceptions, ideas, emotions) are associated with their physical correlatives and motor consequences. Habit is closely related; it is the functional disposition to repeat organic processes. This law of association and habit applies to "organic memory;" thus "associative memory" is fundamental in, and unites, both psychical and physical reactions.

(2) *Inhibition*. The animal organism has a motor character. All sensations and mental states are motor; the entire neuro-muscular organism, mental and motor, acts primarily as a whole, governed by the laws of association, and this is subject to control. "The phenomena of nervous life are the outcome of a contest between what we may call inhibitory, and exciting or augmenting forces" (Foster). It is conceivable that all nerve-centres are normally at all times subject to continuous control or inhibition, and are maintained in a condition of mobile equilibrium by the opposition of this inhibition to their own inherent tendency to discharge (Mercier). "Inhibition is an action which obstructs or impedes another action, and which weakens or arrests it if it was already in action" (Oddi). "Voluntary action is at all times the resultant of the compounding of our impulsions with our inhibitions" (James). "The inhibition of a mental process is always the result of the setting-in of some other mental process" (McDougall). It may be said as a physiological conception that in living substance there are conditions of cohesion and inertia by virtue of the anabolic tendency of its physical and chemical elements; this may be called *physiological inhibition*, and it is the primary factor in the mobile equilibrium conservatively holding the balance against the tendency to discharge induced by constant external stimulation. The psychological conception of the essential physical fact is that one neural process inhibits another; it may be said that as a will-impulse implies a neural process which may inhibit, or excite and augment, some other mental or neural process, this may be called *voluntary inhibition*. The great importance of the study of inhibition, which is only indicated here, lies in its holding an equal and counterbalancing place in mental and physical processes.

(3) *Energy of muscle and nerve.* This refers to the principle of the storage and discharge of energy, and the biological theory that functional activity of a specialized tissue depends primarily upon chemical changes in its individual cells. The fundamental idea is that in the resting state the cell elaborates highly complex compounds and that these break down to yield the energy by which the cell does its work; discharge and restoration of energy is common to both nervous and muscular elements. Hughlings Jackson characterizes the animal organism as "an apparatus for the storage and expenditure of nerve force." These principles are of essential importance in the study of mental disorders. Inasmuch as functional efficiency must be taken as a measure of the available energy, it should be expected that exhausting influences would reduce functional power. Such reductions characterize all forms of the functional psychoses, and the variations of their symptoms are consistent with this principle.

(4) *Physiological use and fatigue, — waste and repair.* The law of use includes the wholesome effects of those just cited; normal use develops functional activity and strengthens power, while disuse weakens function. Overuse begets fatigue, and normal fatigue presents mental as well as physical effects. *Physiological fatigue* may be continued beyond the point of regular recovery by rest and nutrition; it then becomes the *pathological fatigue* of nervous exhaustion or neurasthenia with the characteristic symptom-groups. A functional conception of the significance of these groups of mental and physical symptoms should stimulate not only such a precise observation of them as is needed to constitute "disease-forms" and mature types, but should lead to their being analyzed and traced to their functional sources in the whole organism in accordance with the principles of general pathology. This method reveals the genesis in physical states of some of the most characteristic mental manifestations. Beginning with the fundamental attribute of irritability, for example, wide variations occur within normal limits, but more striking and significant changes appear in all forms of pathological fatigue, and the functional psychoses; the irritable weakness and languor of neurasthenia, and the psycho-motor excitations, retardations, and "confusions" of melancholia and mania are examples. The study of these alterations of irritability involves the whole problem of reflex-action and the mechanism of responses to stimulation of both mental and physical functions. It is to be recognized also that all of these reactions contribute to the sensory returns from the whole organism, — from the viscera, muscles, and even the special senses including the special dermal sensations, to the central nervous system, constituting the kinesthetic and organic sensations. In mental physiology a functional conception of these reactions

reveals their importance for an understanding of the genesis or emotional changes, and the alterations of the affective tone in states of persistent mental depression. The sense of well-being and ill-being depends upon these variations. Most important of all, because so completely neglected in psychiatry, are the bluntings and losses of organic sensations and the consequent effects upon the feeling-tone and ideation; in this regard attention should be called, especially, to a remarkable fact well established in physiology and psychology. It is evident that the normal irritability of nerve and muscle requires the maintenance of a certain chemical constitution; slight variations from this, temporary or continuous, alter or may destroy the irritability. Further, it is noticeable in most cases that the first step toward deterioration is a rise of irritability; the cause being increased or continued, sooner or later exhaustion supervenes, the irritability lessens, and is finally lost.[1] These functional reductions of sensibility, in a wide range of varied degrees and combinations, are constant symptom-factors in psychiatry.

The relation of mental physiology having an essential importance for psychiatry there should be a first reference of all mental symptoms to their functional sources in the organism as far as possible with respect to their correlation and association with alterations of bodily functions. By the genetic method study should begin with the minor changes from normal action; these alterations show intensifications and losses of function, and symptom-groups are modified by their varied combinations.

Mental Physiology and the Functional Psychoses

The true basis of a pathological physiology in psychiatry is mental physiology and its physical correlations of function; variations of nervous and mental reactions in their initial stages may be wholly functional. Approaching the subject newly from this point of view the physician is assumed to know the modes of reaction of the nervous and mental mechanisms and that part of the work done by the nervous system leads to consciousness; he should know also the primary postulates of psychology. Having to study the operations of other minds, he needs to distinguish, in descriptive terms, his own conscious experiences.

A helpful method in psychiatry is to separate the experiences that relate to the outer world from those that belong to the inner life. Professor Sanford presents this idea in discussing the relation of psychology and physics, to which reference has been made. He describes the conscious experiences that may be called physical phenomena: percepts or series of percepts belonging chiefly to the sense-fields of sight, hearing, and touch, including under the latter the kinesthetic senses as well as pressure, heat, and cold; he speaks of these as the senses that mediate the "life of relation" with the world outside our own bodies, — the "physical group of senses." Taste, smell, pain, the general and organic senses — all having little external reference — are not mentioned at all in physics, except incidentally. The method of psychology on the other hand, while not essentially different, has broader outlines; its phenomena are various conscious experiences, including all those with which physics sets out, but also experiences involving pain, organic and general sensations, feelings, emotions, memories, images, volitions, processes of reasoning — and everything that belongs to such experience. Physics dealing with outer experiences only practically works with terms derived exclusively from the kinesthetic and a part of the dermal and visual experience in its spatial function; these are the senses capable of perceiving matter in motion, and the physicist in using their terms excludes reference to the other senses of the physical group, sight, hearing, and touch. Psychology deals with both inner and outer experiences.

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[1] *Am. Text-Book of Physiology*, vol. II, p. 61.

This general view of mental physiology has a special value for psychiatry which it is possible here only to indicate. The conception of a relation between conscious experiences and outer physical phenomena implies an organism, with its special "physical group of senses" in touch with the outer contacts, acting as a medium of transmission between the two; this medium may be conceived as forming also a *somatic* group of senses in the paths of communication. But this mechanism of transmission does not afford, even normally, open ways without friction or obstruction; to its reports of contacts with the outer "life of relation" it adds the multitude of returns with all their variations from its own physical workings, and for this process the same mechanism of kinesthetic and other senses, in a new grouping with others, including the organic and general sensations, is used. In abnormal as well as normal conditions these returns, however imperfect, stand for the truth and the whole truth in conscious experience; in health we think as little as possible of the medium of transmission, and in all conditions of well-being or ill-being we can only describe our organic feelings in general terms. We do not recognize for the most part the sources of these sensations, yet they have a controlling influence upon our minds. These considerations indicate three groupings of the functions of the sensory mechanisms of conscious experiences: (1) the physical group of senses of the outer "life of relation;" (2) the somatic group of senses of the inner life — our conscious experiences of our own bodies; (3) the central psychical life, which includes both of the other groups of conscious experiences, besides those belonging distinctly to its mental aspects. The interest of this to psychiatry is that comparatively little attention has been given to this inner sensory field of the sources of conscious experiences; yet, it may be said, here are the conditions and the very material of bodily and mental stimulations and sensations with which the mental work is done. These explaining principles have been almost wholly omitted from the accepted formulae of the conceptions of modern advanced psychiatry which has chiefly concerned itself with the motor aspects of mental life and expression. These physiological references are needed to explain many of the symptoms of the psychoses and should have their full value in the formulation of the principles of mental physiology and psychiatry.

A functional conception of mental pathology [1] directs observation to the first and smallest departures from normal action, upon the principle that all variations of a pathological character are subject to the laws of normal function acting under abnormal conditions. The study of the development of symptoms is equivalent to noting the genesis and progress of the conflict between the functional energies and the abnormal conditions. Symptoms as functional modifications are the results in changes of action, — organic effects are the results in changes of structure; by the genetic method the sequences of functional phenomena are noted; in the functional psychoses there are variations of functional efficiency manifested by its reductions and recoveries. The following characterization in outline of the psychoses is an application of the functional principles referred to in the foregoing pages. For the purpose of tracing the several orders of symptom-factors from their genesis in functional sources they can be considered most simply under the divisions of the mental elements — intellect, feeling, and will, as these terms are used in modern psychology for purposes of classification.

Characterization of the Psychoses according to Functional Principles

1. THE FUNCTIONAL PSYCHOSES. A study of the large group of cases of non-deteriorating mental disorder yields certain general conclusions as to what may result to the normal well-endowed individual when subjected to the effects of use, disuse, overuse, and stress. Beginning with the least degrees of decline of functional vigor, below normal fatigue, there is no point in the declension where a line can be drawn definitely marking a change from one named

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[1] Cf. Barker, L. F., *Methods in Medicine*, *Boston Med. & Surg. Jour.*, June, 1905. Referring to the value of a functional conception of pathology, it is also said that "as medicine has become more scientific the mind has ceased to be satisfied with such descriptive classifications as the clinical symptoms and syndromes represent and with 'clinical types' set up, and is ever on the alert to replace them by classifications of a developmental or genetic character." Quoted from an address before the Mass. Med. Soc. published while this paper was in manuscript.

"clinical type" to another, down to the lowest degrees of vital energy and complete loss of voluntary function. Throughout all observations of these changes the essential principle of variations of irritability is never to be lost sight of nor the fact that the first step toward deterioration of function is characterized by a rise of irritability. Another pervading principle is that among the multiple functional mechanisms failure of energy is unequal, and that changes and losses of irritability must apply as much to sensory as to motor function. The word "psychosis" can be used most profitably as correlative with "neurosis," and as including both its proper psychological and pathological meanings, leaving the differentiations of sanity and insanity to be indicated by those words. A basis of inquiry, as above described, prepares the way for the examination that comes first in order of the initial departures from mental integrity, viz., the affections called imperative and fixed ideas, and the primary asthenic conditions of neurasthenia before the after-effects of chronic states have supervened.

Insistent and fixed ideas refer to a wide range of kindred cases of affections that can happen to sound minds in persons neither temporarily nor constitutionally neurasthenic. The functional elements are normal and the affections may attain characteristic forms in normal minds; but this happens to them more readily when there is neurasthenic reduction of inhibitory energy and greater degrees of intensity and persistence occur in association with constitutional instability. All observant sane persons estimate the purposes of others by interpretations of their speech and behavior, and thereto fittingly adapt their own conduct influenced by inferences and judgments in a manner that would indicate "paranoid" suspicion under certain circumstances. Inasmuch as this is a universal, functional, self-protective principle, sane persons have normally the functional disposition to produce ideas of suspicion and persecution, but well-balanced minds control thought and speech. In *any psychosis*, however, associated with asthenic conditions there may be "paranoid forms" not belonging to that psychosis as essential to the symptom-complex; this reaction is liable to become casually intensified or further developed and fixed by habit. In many cases not "psychasthenic," nor physically neurasthenic, the affection is purely a functional accident; it may involve all forms of emotional reactions, other than "phobias," and many cases recover.

Neurasthenia, in its early conditions, uncomplicated by the effects of habit, presents the same elements, in mild degrees of functional reduction, that characterize their greatly varied combinations in the symptom-complexes of the graver conditions of melancholia, mania, and exhaustion psychosis or confusional insanity. These neurasthenic conditions may occur in all persons, under sufficient stress, but when there is constitutional weakness the power of resistance is less. The functional elements of the organism, all working together, constitute combinations of community-work of extreme complexity; these elements being unequally reduced in efficiency the "clinical types" are very much varied. A method of analysis of symptoms with the endeavor to estimate their functional values and their relations to their physiological sources will appear under the following topics:

The functional psychoses constituting the main group of non-deteriorating affections pathologically regarded as insanities, all have a basis of some kind or degree of asthenic reduction of functional efficiency; as already indicated, these may include the whole range of degrees from simple cases of nervous exhaustion downward through the simple and pronounced cases of melancholia and mania, including all varieties of phases and combinations of the symptom-elements; also including the more actively induced exhaustion psychoses and confusional deliria. Functionally considered, it is proper to regard all these cases as "functional psychoses" until proved to the contrary. Function comes first as the present criterion; organic change is a result. Cases carefully diagnosticated characteristically tend to recovery. The designations, neurasthenia, melancholia, mania, etc., are simply valuable descriptive terms; they are thus not correct names of diseases as clinical types and we have yet to study broadly the genesis and development of these conditions. By the functional method we have merely advanced, as yet, little beyond the general fact that two classifications may be made of the psychoses — the non-deteriorating, and the deteriorating. By the morphological, clinical-type method there is a singular lack of success in adopting principles of valuation of symptoms by which men of good minds can reach like conclusions. We are not yet ready to determine species; this should be aided by the study of the genetic character of the symptom-elements.

The significance of the unifying characters of the non-deteriorating range of psychoses may be made much clearer by grouping them according to the functional sources of the symptoms and their own natures. The symptom-factors thus fall into natural groups, which should be studied with complete freedom from preconceptions of "disease-forms." No more is attempted here than to harmonize these groups with the elementary postulates of psychology, and with the general physiological facts heretofore cited.

(1) *Feeling.* (The feelings and emotions.) The emotional variations that are pathologically persistent are in close relation with the changes of bodily states which are represented in the central nervous system by the organic, kinesthetic, and general sensations; the sum of these has, physiologically, a strong influence upon mental feeling,

and therefore in pathological conditions the emotional tone of the psychical sphere corresponds with the sense of personality by "states of mental depression" (melancholia) associated with malaise and ill-being, and "states of mental exaltation" (mania) with sense of well-being and false euphoria. The complex sources of the sense of body have been described and the changes of irritability due to fatigue and other causes; the consequent variations of the sense of physical pleasure and pain are closely connected with the rise and decline of irritability, its intensifications and losses, but not with parallel changes.

In the emotional states of "neurasthenia" the depression is variable; of "melancholia," persistent; in both the feeling-tone may be combined in various ways with the first degree of functional deterioration of irritability marked by agitation, restlessness, "irritable weakness" (psycho-motor excitation), or by dullness, slowness, languor (psycho-motor retardation). In nervous exhaustion and melancholia the feeling-tone is constantly influenced by bluntings and losses of organic sensation, strikingly shown in the loss of the sense of fatigue — "fatigue-anesthesia," and the various unequally distributed conditions described in the natural order of decline as hyperesthesia, hypoesthesia, paresthesia, and anesthesia; also ease and obstruction of motor expression have their reflex influence upon the affective states as in a feeling of facility, or the "sense of inadequacy" and the "sense of effort." [1] Hopelessness, introspection, retrospection, apprehension, self-reproach, are logical consequences. All these variations are persistent intensifications and differences of the normal connections of ideas and emotions, with their correlated physical reactions; the persistence of morbid emotional reactions indicates deteriorated body-states.

In the emotional states of "mania" there is the characteristic exaltation and exhilaration; but in many cases there is depression of feeling of the type shown by anger in its origin from painful states of irritation, and by distressing delusions and aggressiveness. These two prominent types of feeling-tone are associated with corresponding variations of irritability marked by its rise from moderate to high degrees of psycho-motor excitation, shown mentally in "flight of ideas," corresponding to the agitation and irritable weaknesses in melancholia, — sometimes more extreme and sometimes reduced and lost. The clinical pictures in some cases may indicate a simple absence of painful irritation, but they certainly show, characteristically, the false euphoria of blunted sensations, as in alcoholic intoxication.

(2) *Intellect.* (Sensations — perceptions and ideas.) The "thinking process," as it is rather vaguely called, may be definitely con-

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[1] Cf. Cowles, E., *op. cit.*, *Neurasthenia and its Mental Symptoms*, 1891.

ceived to include the ideational reactions of the stream of consciousness, constituted of the association-processes in combination with the inhibitory or exciting control of the will working through attention and apperception; the emotional factor enters into the combination and modifies the "thinking process" with intensifications of interest and motive influences. It is impossible to describe these function-factors separately because they all work together. The character of the ideas — the sensations revived by memory in the association-process, whether depressed in melancholia, or exalted in mania, is in harmony with the emotional tone as it is "lowered" or "exalted." The time-element in the processes of the stream of consciousness varies with the rise in irritability and especially with the coincident reduction of inhibition. This, in mania, with the intensification due to irritability, produces "flight of ideas" with quick reactions and superficial associations. The tendency is to increasing weakness, reduction of clearness, incoherence, and final arrest of mental functions in confusion or stupor. With disordered perceptions there are illusions and hallucinations; delusions arise. Maniacal states represent graver degrees of derangement than melancholia, and a lower level of functional reduction, especially of inhibition. The more profound conditions of acute exhaustion (confusional insanity, exhaustion psychosis) occur sharply by themselves from strongly exhausting influences and are varied manifestations of delirium; these may supervene in the severer types of both melancholia and mania.

(3) *Will.* (Inhibition — attention and apperception.) In the sense that acts of the will are such acts only as cannot be inattentively performed it produces exciting or augmenting effects in the "thinking process," or inhibiting effects; working through attention and apperception its function of control appears in voluntary inhibition, and this has been described in part in connection with the other elementary functions and in the reference to the physiological law of inhibition. Normally inhibition, both physiological and voluntary, stands in mobile equilibrium with the tendency of all conscious and neural excitations to discharge into motor effects, open or concealed within the organism. In the incessant change and succession in the train of ideas in consciousness the attention holds the chosen or attracting idea in the interplay of neural processes and thus inhibits its tendency to pass away, other items being held with it in reasoning, and apperception being a special form of the same controlling influence. This inhibitory function is a true index of the integrity of vital energy; it is regularly reduced in efficiency with asthenic reduction of the nervous forces. Voluntary inhibition is variably reduced in neurasthenia, persistently in melancholia, and greatly so in mania with loss in delirium.

(4) *Organic Sensations and States.* (General and kinesthetic sensations.) The importance has been shown of these function-factors of the "somatic group of senses," in respect to the representations they bring into conscious experiences concerning the inner physical life of the body. In health the sensory and motor reactions of our bodies, and our conscious experiences, are adjusted to contacts with the environment within normal limits; the organic and kinesthetic senses normally contribute to the general welfare with only salutary interferences, and these being mostly unnoticed we habitually ignore their existence. It is in disordered physical conditions that the abnormal influences arise and interfere with and derange the experiences of the mental life; they are general and vague in character, but are of essential significance, though only described as subjective experiences. The phenomena of changes of excitability and loss of function are well known and variously described; an interference with the functions of any one system will disturb the normal functional equilibrium that must of necessity exist in the action of the whole.[1] The principle of localized variations of irritability, as in the neuroses, applies to all functioning groups of cellular mechanisms; the threshold of excitation may be raised or lowered in any of the sensory, motor, or central and psychical parts of the reflex mechanisms. Upon these changes may be predicated all the phenomena of psycho-sensory and psycho-motor excitation and retardation, conditions that appear in some kind or degree in the whole range of the functional psychoses. These variations may be ascribed to reductions of the nutritional maintenance of the vital energies. Hyperesthesia and hyperkinesis are the complementary manifestations that betoken fatigue, or equivalent weakness from some cause, of the physiological inhibitory energy; this condition is often associated with anesthesia of the fatigue-sense in the same case.

It should be noted that the changes of feeling-tone, of motility, and of control do not run parallel to each other; hence the differences of the clinical pictures presented by typical melancholia and mania, and the so-called "mixed cases;" melancholia presents two principal types — emotional depression with excitation and retardation; mania presents emotional exaltation with excitation, and sometimes there are painful states of consciousness and the acute reductions of function in exhaustion and stupor. There are numerous phases in the unified melancholia and mania as constituting one general group of variations of functional disorders presenting clinical phenomena apparently widely divergent as "clinical types," but falling into harmonious relations when explained consistently with their developmental and genetic character.

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[1] Cf. Mott, F. W., *The Degeneration of the Neuroses.*

2. THE DETERIORATING PSYCHOSES. These psychoses have an important relation with the *functional psychoses,* which should be mentioned here. They are characterized by persistent functional deterioration and tend to dementia; this is consistent with the opposing fact that the vital energies of the life-process sometimes appear to overcome in recovery the interferences with their normal action. It has been said that the functional psychoses tend to recovery; yet the failure to recover in some cases may be consistently referred to constitutional weakness or the loss of vigor in old age. This does not imply that heredity is an essential cause of mental disease; "neuropathic" persons have less endurance against all adverse influences. Among the *deteriorating psychoses* the first place is given to a large group called "dementia precox;" its general form is not clearly differentiated, nor its special divisions; no common basis is implied in the designations hebephrenia (mental weakness), katatonia (motility disorders), paranoid forms (insistent and imperative conceptions). A single case may change from one "form" to another, and the recognition of some constant characters is required to unify all the "forms;" the common fact of dementia is shown in the deterioration of capacity that may occur in any of the functional mental elements, varied in different cases; this implies structural changes. The character of the failure is revealed in the quiescent states after the subsidence of active symptoms. The most common fact is the deep-seated deterioration of the emotional nature; hence the characteristic indifference and apathy which favors the development of habit automatisms, etc. Concerning this large group of deteriorating psychoses, regarded as above stated, and including also the few other "disease-forms" at present accepted as such, some general conclusions now appear with respect to the functional psychoses.

Mental Physiology and the Functional Psychoses, continued

The unification of the functional psychoses can only be indicated here with respect to the explanations and conclusions reached during some years of teaching the principle that each of the groups conveniently designated neurasthenia, melancholia, mania, etc., simply includes variations in combinations of different degrees of functional disorder of the same physical and mental elements. The essential unity of melancholia and mania was recognized by Griesinger and others with differing explanations; modern physiology and psychology broaden and simplify the whole subject with better explanations of general principles.

In recent psychiatry there is an evident tendency to the unification of the psychoses.

A significant contribution has been made by Dana;[1] in his large neurological experience he has seen much to favor the idea that most neurasthenias are mental cases, or non-insane psychoses; the term phrenasthenia is used for a special group of neurasthenic or degenerative psychoses including mainly those described by Janet as psychasthenia; it is said that an innate constitutional weakness underlies all the chief non-accidental functional insanities. There is much reason for a simplifying psychiatrical conception, complementary to Dana's view, that not only most but all functional mental cases are subjects of asthenic reduction of functional efficiency and are neurasthenic. The tendency is notable in the remarkable studies of Janet in which he reaches the conclusion by psychological analysis that many of the apparently diverse psycho-neuroses may be unified under the one principle of psychasthenia; this implies a general and special insufficiency in all the phenomena and is at the same time neurasthenia; these affections represent regular degrees of lowering of functional efficiency.

The genetic method leads to a comprehensive view of all the psycho-neuroses. Considered biologically and physiologically neurasthenia, phrenasthenia, psychasthenia and all the functional psychoses are modifications of functional characters. Whether these modifications were acquired newly by the individual himself, or by his ancestor and thereafter transmitted as though they were inherent variations, the problem is essentially the same. However perverted, distorted, and anomalous the functional phenomena of vital activity may be, they must be traced back to the first interferences with the physiological elements to find their explanations in their genesis. We may assume that all normal adult individuals are subject to certain acquirable functional modifications — numerous and complex, thus forming the symptom-groups called neurasthenia, melancholia, and mania, for example; all abnormal persons are subject not only to the same changes, but to something more and something different, and these additions may be simply special variations of intensity, or degrees of impairment, or of differences pointing to other than functional explanations. A general principle in mental pathology may be derived from these considerations. Whatever the form of a deteriorating psychosis, it has its own pathological characters; but superimposed upon these symptom-factors, and relatively superficial, neurasthenic manifestations commonly appear, and there may be episodes, more or less transitory, of manifestations of the functional psychoses. This occurs notably in the early stages of dementia precox and manifests the practical concurrence of two diseases, viz., the per-

[1] Dana, C. L., *The Partial Passing of Neurasthenia, Boston Med. and Surg. Jour.*, vol. CL, 1904.

manent deteriorating psychosis and the transitory phases (melancholic, maniacal, and paranoid) of the functional psychosis. This principle accounts also for the fact of there being maniacal as well as melancholic types, and the "paranoid conditions," in the "involution psychoses;" this principle is already well recognized in respect to the neurasthenic, melancholic, and maniacal modes of onset of paresis; and to the same types of functional disorder, and tendency to obsessing suspicious and delusional ideas, in senile insanity in which active symptoms may measurably or wholly disappear. All the psychoses called functional for purposes of classification, and being nearest to normal, constitute the main division of the psychoses (considered as mental disorders); all the psychoses called deteriorating, and being exceptions to the others, constitute the minor division. In these the fact that in some particulars the reductions of functional efficiency remain permanently deteriorating constitutes dementia, which implies some form of structural change, though none strictly characteristic has yet been found. The pathological principle here suggested leads to a practical method of analysis of the symptom-factors of all possible forms of deteriorating psychoses. The first step is the distinction of the purely functional modifications referable to physiological sources; these relate to variations of the fundamental irritability as explanatory of changes of motility and of the sensibilities and emotional tone, all being comprehended broadly in relation with the "somatic group of senses;" closely kindred with these are the reductions of function of the processes of association, memory, attention, inhibition, etc. Holding apart these phenomena of the main division of psychoses as being included in the functional conception of their pathology, and as explainable through their genetic and developmental character, there remain, of the symptom-factors of a deteriorating psychosis, those that point to the causes of the special deterioration. This helps to define the problem of research for anatomical explanations. It should not escape observation that when there is "innate constitutional weakness" in cases belonging to the main group of functional psychoses, special modifications may be noted in the symptom-factors, especially of the attention and inhibition element whose reduction is the most constant and characteristic fact of constitutional insufficiency. It is in these conditions that the law of habit has its most potent and perpetuating influence. The functional psychoses, including those answering to the definition of "a typical form of insanity," present some points of special interest when analyzed in accordance with the method and principles examined in the foregoing pages. Reference has been made to Griesinger's descriptive definitions of melancholia as "states of mental depression" and mania as "states of mental exaltation." During more than half a century these designations have held their places in psychiatry; the search for more satisfactory statements has not been altogether successful. The difference of the emotional tone is the criterion, but it is not a wholly true one. The depression in melancholia is consistent because the "somatic senses" retain enough of normal function to report truly to consciousness the fact of ill-being of the body; but in mania the exaltation is not constant, the physical correlatives of the feeling-tone are more disordered by reductions and losses yielding more irritating excitations and in many cases a fictitious sense of well-being. But the "somatic senses" produce other equally important symptom-factors in the changes of motility; in melancholia with impaired inhibition there are both psycho-sensory and motor excitations and retardations, — in mania, with graver changes and losses of inhibition, motility is more disordered. The word melancholia, by long usage and observation of the facts, really stands correctly in the recognition of its meaning all of its well-known symptom-factors other than emotional depression; the word mania, meaning madness, stands equally well for both its emotional variations and its motor excitement. In mania there is graver derangement of the "thinking process" and its "states" are at a lower level of reduction than melancholia. These references though meager serve to show that the terms melancholia and mania are well understood as including a great variety of states of varied combinations and proportions of their symptom-factors; besides the many typical cases of each group there are found to be very many "mixed cases." There are many phases, and a two-phase conception to represent the original groups of "states" does not hold good; for example, taking out the emotional depression from one group, and the motor excitation from the other, in order to designate the distinction of the phases and to characterize the compound "disease-form," leads to the exclusion from it of the very essential psycho-motor excitation often associated with the depression in the former group, and to overlooking the significance of the emotional changes in the latter. An adequate study of the "somatic group of senses," as suggested here, should help to clarify the whole matter. Compound designations for the unified symptom-groups yet suggested do not satisfy the requirements so well as their simple combination in "melancholia — mania." The psychoses cannot be limited to the insanities; we must speak of the "non-insane psychoses," and in psychology the word refers to normal function. It might be said that the first step in the classification of mental diseases discovers two great divisions: *functional insanity* and *deteriorating insanity.*

This discussion of the thesis that the problem of psychiatry is in the functional psychoses, required first an examination of the terms and conditions of the problem. This necessitated an inquiry concerning certain principles and conclusions of the biological and medical sciences that have had a controlling influence in psychiatry. Morphological conceptions being dominant in medicine, it was found also that a number of terms and phrases are so commonly employed in medicine that their use has been compelled in psychiatry, although they embody conceptions and theories inconsistent with its dependence upon functional conceptions of mental pathology. The inquiry having led to the conclusion that the physiology of the life-process is the first recourse for psychiatry, in the search for explaining principles it becomes necessary to be emancipated from all preconceptions. The functional conceptions, being framed, and applied consistently with the facts of physiology and psychology, lead to a recognition of the developmental and genetic character of the functional modifications, and indicate their sources in physiological facts. A clearer idea is gained of the relation of conscious experiences to body states, and of the influence of the "somatic group of senses" in the relations of the conditions of the whole organism to the mental states. The dependence of all functional phenomena upon the processes of nutrition and metabolism for the maintenance of the nervous and mental mechanisms points to the fundamental importance of pathological physiology and chemistry. Physiological and psychological experiment in the immediate clinical examination of functional modifications shown in symptoms helps to determine the physiological sources of the contributing disorders in the whole body as well as the central nervous system.

The psychiatrist inclined to inquiry finds, in the pursuance of his practical work, that as a physician he must treat the whole body, and that a functional conception of mental diseases leads to treatment. Psychiatry belongs to general medicine and mental disease like bodily disease is not an entity nor an agency, but the result of normal function acting under abnormal conditions; the problem requires the investigation of the developmental and genetic character of functional modifications.

SECTION H — SURGERY

SECTION H — SURGERY

(*Hall* 13, *September* 23, 10 *a. m.*)

CHAIRMAN: PROFESSOR CARL BECK, Post-Graduate Medical School, New York.
SPEAKER: DR. FREDERIC S. DENNIS, F.R.C.S., Cornell Medical College, New York City.
SECRETARY: DR. J. F. BINNIE, Kansas City, Mo.

THE HISTORY AND DEVELOPMENT OF SURGERY DURING THE PAST CENTURY

BY FREDERIC S. DENNIS

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THE first word of the speaker on this occasion must be a personal one of respectful acknowledgment. To be invited by the administrative board to deliver an address upon any theme before this august Congress, composed as it is of many of the world's most distinguished men of science, is a distinction which any one might justly prize. But to be chosen as the orator upon a topic so important, far-reaching, and comprehensive as the history and development of surgery during the past century is an honor so exalted that while it pleasantly gratifies, it also most seriously appalls.

Permit me at the outset to record my profound and grateful appreciation of the high honor thus conferred, and at the same time to express the hesitation which I feel in attempting to handle so great a theme within the necessary limitations of the hour. It is obvious that the task is as fascinating as it is difficult. It is undertaken at the earnest solicitation of friends who have much stronger confidence than the speaker in his ability to narrate in a fitting way the triumphs of our great science.

To weigh the surgical events of a hundred years ago, and the motives which gave rise to them, requires us to summon to our thought, as far as possible all the circumstances of that period. Only when this retrospect is made, and the meager results then attained by surgery, are compared with its notable achievements in the present day, can the idea be fully grasped of how great, how wonderful, how grand, has been the progress during the past century. The advances which have been made in every department of human activity, the victories gained in every field, the innumerable inventions, the marvelous discoveries, the daring exploits carried forward to successful completion, the magnificent results secured along all scientific lines, are all discussed and celebrated in the meeting of this International Congress. But while the other sciences have indeed thrilling stories to relate, and can point with just pride to excellent deeds performed, the science of surgery stands out in bold relief and conspicuous grandeur, apart from and above the others, in that it deals directly with human life, that most precious of mortal possessions, often lending to it not only a helping but a saving hand. At the same time its story is so simple and yet so grand that the child and savant may alike participate in the pleasure which the wonderful narrative is fitted to convey.

Surgery as a science made no profound impression upon the world until about a century ago. But from that time to the present the almost miraculous works which it has wrought, increasingly marvelous with every passing year, have aroused astonishment and admiration in every quarter of the globe.

In order to appreciate what surgery has accomplished, it is necessary to refer briefly to its status prior to 1800. A little over a century ago surgery as a science had no existence. It had no definite or dignified position. It received no aid or support from reigning monarchs or kings. It was in the hands of charlatans and quacks and barbers, and it was practiced with some few exceptions by uneducated and irresponsible men. It was only in 1800 that surgery was divorced from the traditions of the past and was given a place among the sciences. It was in 1800 that the Royal College of Surgeons obtained its charter from Parliament, which had refused over and over again to grant it. So bitter was the opposition to granting a charter to the "Company of Surgeons" that Lord Thurlow is said to have proclaimed in the House of Lords that "there is no more science in surgery than in butchering." It was only by an appeal to King George the Third that this charter was finally obtained. In marked contrast to this attitude of Parliament was the scene enacted at the Centenary of the College of Surgeons, a few years ago. Here were assembled the foremost statesmen of England, and the leading scientists of the world, to do honor to the occasion. The King himself joined in the banquet as an honorary member of the Guild. During all these centuries prior to 1800, as has already been stated, surgery had no established place among the sciences. Medicine, on the other hand, had a well-defined and honorable status. It received abundant help and liberal support from kings and rulers. Thus it becomes evident how bitter the struggle has been for surgery to establish its claim to honorable and dignified recognition. Thus it becomes apparent that the difficulties to be overcome to establish that recognition were then insurmountable. This is not to be wondered at when pain in surgical operations, inability to control hemorrhage, and prevention of blood-poisoning, were the obstacles to the successful practice of the art. These evils retarded the growth of surgery. Their removal since 1800, and chiefly during the past quarter of a century, has cleared the way for the achievements of the present day. From Hippocrates, who was born 460 B. C., to 1800 A. D., surgery made little advance. It was practiced by illiterate men, with here and there a masterful mind groping in the dark for light. There were two great discoveries prior to 1800 that had an influence on the progress of surgery after that time, and without which surgery could never have become a recognized science. The first discovery refers to the circulation of the blood, which was made by Harvey in 1628, and the further discovery of the capillary system by Malpighi in 1661. The fearful dread of hemorrhage from an unknown source prevented any operations except those of dire necessity, which were generally performed through dead and gangrenous tissue. The second discovery refers to inflammation, the healing of wounds by blood-clot, and the ligation of the vessels in their continuity, by John Hunter, who was born in 1728. These two great discoveries prior to 1800, like the two great discoveries after 1800, viz., anesthesia and antiseptics, have enabled surgery to establish its just claim to recognition among the sciences. These four great discoveries, the circulation of the blood, the repair of wounds, anesthesia, and antiseptics, are the four corner-stones upon which a superstructure has been erected that has become a veritable temple of science, the dimensions of which eclipse in grandeur all other temples.

The progress has been greater during the past century than in all the preceding centuries since the beginning of the world. This progress which surgery has made is due, in great part, to the dissemination of medical literature, to the formation of medical libraries, to the organization of modern hospitals, to the equipment of scientific laboratories, to the foundation of medical schools, to the establishment of medical museums, to the organization of training-schools for nurses, and, finally, to the two transcendent discoveries — anesthesia and antiseptics. That medical literature has had much to do with the advance of surgery during the past century is evident when it is shown that at the beginning of the Revolutionary

War there was only one medical book, three reprints, and about 20 pamphlets by American authors, while to-day there is on the average one new book for each working day in the year, 300 journals, and 5000 original journal articles. American writers are publishing annually at least 500 medical volumes, to say nothing of the issuance of nearly 10,000 journal articles each year. In the department of surgery alone, during the two years of 1879-1880, there were written in America no less than 45 surgical books of importance and value, together with 1717 journal articles beside, and from this record of nearly a quarter of a century ago some idea can be gained of what surgical literature has accomplished at the present time.

That the foundation of medical libraries has had much to do with the progress of surgery becomes manifest when it is considered that a hundred years ago there were in this country only about 250 medical volumes, all told, while to-day there are nearly 160,000 volumes in the libraries of medical colleges alone, to say nothing of the large and general medical libraries throughout the country, without mentioning the thousands and thousands of volumes in the medical libraries in Europe.

That modern hospitals have had much to do with the advance of surgery is apparent when it is remembered that there were scarcely any hospitals a hundred years ago, while to-day they crowd nearly every city and town. This statement is emphasized by the fact that in New York and in Philadelphia there are four free beds to every 1000 of their respective populations; and by the further fact that any American city without adequate hospital accommodations is looked upon as in disgrace and behind the age; and, further, that the 433 hospitals in this country which maintain training-schools for nurses exceed in value $73,000,000, and their endowments exceed $18,000,000. These figures represent less than a fourth of hospital wealth, since many of the hospitals maintain no training-schools.

That the establishment of scientific laboratories has been a potent factor in surgical progress is proved by the fact that millions of dollars have been recently devoted to this purpose, and the work performed in these laboratories has had a tremendous influence upon the world. To Andrew Carnegie is due the credit of building the first purely scientific laboratory for medical and surgical research in this country; and from his example other like laboratories have been established in the land, until now America eclipses the world in the wealth and magnificence of its scientific institutions. The Laboratory of Hygiene in Philadelphia and the Caroline Brewer Croft Fund for the study of cancer at Harvard University are worthy of mention. Many well-equipped laboratories have been built in connection with large universities; while the magnificent gift of the Rockefeller Institute for Original Research affords another example of the influence which these establishments exercise in the development of medicine and surgery. In the Carnegie Institute there is a fund yielding over $300,000 per year to be expended on its work. In a conservative estimate the property investment in all kinds of medical institutions, such as hospitals, laboratories, medical colleges, health department bureaus, training-schools for nurses, etc., is three or four hundred millions of dollars, not to mention the endowment funds.

That the foundation of medical schools has had a great influence in the history and development of surgery becomes apparent when it is considered that about a hundred years ago there were only 200 medical men in practice in this country, while to-day there are over 100,000 workers in the field. A century ago our own country could boast of only two small medical schools, while now there are 154 medical schools, affording instruction to 26,821 students annually, many of whom will work in the chosen field of surgery; and nearly all of these medical schools are an integral part of some great university; $418,000,000 scarcely represents the value of the property belonging to medical schools, and $8,000,000 their endowment.

The recent munificent gift by Colonel Payne to Cornell University for the establishment of a medical department in New York City marks a most important epoch in the education of the physician and surgeon in the country. It is a fact worthy of honorable mention that the wealthy men of the present century have contributed most liberally to the science of medicine, as is obvious from a review of the recent different gifts and endowments amounting to many millions, especially during the past few years.

That the establishment of training-schools for nurses has had much to do with the progress of surgery is obvious when it is considered that about a quarter of a century ago there was not an American trained nurse, if any, in the United States. To-day there are about 11,000 pupils, and nearly 20,000 graduates. The inauguration of the first training-school for nurses in the United States at Bellevue Hospital in 1873 marks an important epoch in the history of modern surgery in this country. From the initial school at Bellevue others have been established throughout the country, and now every important hospital in the land has a competent corps of trained nurses as an essential feature of the modern hospital. The far-reaching and widespread influence of the Bellevue training-school, which was the first in this country to grant a diploma, cannot be over-estimated, as it relates to the improvement in the care of the sick, to the establishment of other training-schools, and to the opportunity offered to make possible the practice of surgery of the present century. The valuable services of Mrs. W. H. Osborn for nearly thirty consecutive years and the untiring labors of Mrs. W. P. Griffin, who has been its faithful president for nearly twenty-one years, entitles them to a high place of honor in the estimation of the medical profession. The progress of surgery in this country has been largely influenced by the help and aid which this department of philanthropy has offered to suffering humanity.

It is indeed a truth that without the Bellevue Training-School for Nurses, and the influences which have sprung from it, the surgery of the present century and notably of the last quarter of a century in America would not have been possible. The lady managers of the noble charity can feel a just pride in the silent and beneficent work which they have accomplished on behalf of suffering mankind, and can feel, moreover, that they have participated in the great work that marks a milestone in the progress of surgical science in the United States.

That medical museums have exerted an important influence is apparent from the fact that a century ago there were none in the land, while now there are many. Not a few of these are admirably equipped and appointed. They contain over 200,000 gross specimens. For their maintenance nearly $200,000 is expended annually, or one dollar each for the preservation of each specimen.

The history of surgery during the past century furnishes one of the most remarkable chapters in human affairs. It is obvious that life is the most important factor and element in the history of the race. Without life, of what avail is all else in the world? Surgery has to do with the saving of human life, and as such is the grandest and noblest of the sciences, and the most beneficent to mankind. A study of its development brings us face to face with the most startling and miraculous discoveries which have had an influence upon the health, the happiness, and the mortality of the race.

It is only necessary to remember that a little over a hundred years ago there were scenes enacted in the name of surgery which eclipsed in horror the frightful cruelty of the Spanish Inquisition, the untold miseries of the Bastile, the indescribable sufferings of the Black Hole of Calcutta, the excruciating pains of the Turkish bastinado, and the cruel massacre of the Huguenots. One shudders at the horrible cruelties which were perpetrated on withering mortals in the name of surgery. The records of suffering which have come down to us through the years of the century have no counterpart in the various experiences of modern life. Patients were held down upon the operating-table by brute force and were operated upon while in the full possession of their senses; they were heard to shriek and to cry out in heartrending screams for a discontinuation of their tortures; they were incised with red-hot knives, and they were compelled to have their wounds dipped in a caldron of seething tar to control hemorrhage.

Through God's infinite mercy in the progress of the century, all this is now changed. The patient falls asleep without a struggle; and when he awakens to consciousness the operation is finished. The convalescence is fever-free and painless; the mortality is reduced almost to zero in many cases, and the operation itself robbed of all its horrors. The evolution which surgery has made to effect such a wonderful change is one of the most fascinating studies in the world's history.

To dwell upon this in orderly manner is the purpose of the present discourse. In order to simplify as much as possible the comprehensive subject, it is necessary to divide it into four different parts, and to trace the rise, progress, and development of surgery in its triumphal march as it pertains to these four great events in history, during the past century.

1. The discovery and employment of anesthetics.
2. The discovery and practice of antiseptics.
3. The discovery and application of modern therapeutics and of new diagnostic aids.
4. The improvement of old and the discovery of new operations with their mortality.

1. *The Discovery and Employment of Anesthetics.* Among the important events in the history of mankind which have been far-reaching and beneficent in their influence, the discovery of anesthesia easily stands in the foremost ranks. What greater blessing has science ever conferred upon the human race? Other discoveries and inventions have indeed been revolutionary in their results for social advancement and comfort; but anesthesia outranks them all, in its combinations of kindness and power at a point of unutterable need. This wonderful boon to suffering humanity, now gratefully in use throughout the civilized world, comes from our own land—America. No other nation has presumed to lay the slightest claim to any priority in its discovery. Anesthesia with its world-wide blessings is confessedly American.

In 1844, Horace Wells, a dentist of Hartford, Conn., heard a lecture by Colton on nitrous oxid gas. In illustration of the lecture the gas was administered to a person in the audience. The man fell to the floor; but was insensible of his fall, confessing afterward that he was absolutely unconscious. This episode caused Wells to think that perhaps the gas could be utilized in dentistry for the painless extraction of teeth. With a true courage of his convictions he tried the experiment upon himself, inhaling the gas, and having one of his own teeth extracted by his assistant. When a few moments afterward, he returned to consciousness, he cried out in his enthusiasm, "a new era has dawned upon the world, I did not feel it more than a pin-prick," and Horace Wells was a greater prophet than ever he dreamed himself to be in the moment of wild excitement.

In 1844, William Morton, a Boston dentist, heard that sulfuric ether could be inhaled in small quantities, and that it produced a certain degree of unconsciousness. Like Wells, Morton immediately tried the experiment upon himself, a daring thing to do. After inhaling the ether he became insensible for eight minutes. The moment he came to himself, the thought flashed through his mind that in ether was a vapor which would produce insensibility for a longer period than gas, and that here was an anesthetic peculiarly suitable for surgical work. Accordingly, he sought his opportunity. It came on October 16, 1846, a red-letter day in the history of surgery, not only in America, but throughout the world. That day Morton administered ether to a patient in the Massachusetts General Hospital, in Boston, who was to be operated upon by Warren for the removal of a vascular tumor. Under the influence of ether the patient remained unconscious during the operation, which was highly successful. To be sure Crawford W. Long had administered ether prior to this time, but Long did not quite trust the evidence of his own experiment, and feared that his success might be due to an incidental hypnotic influence. The work of Jackson should also be mentioned, since as a chemist he made ether; but it was Morton who really proclaimed the discovery of anesthesia in an emphatic way, so as to arrest universal attention, and introduce a new epoch in surgical science.

November, 1847, was another red-letter day in the progress of surgery, for on that day Simpson, the famous Scotchman, made announcement of chloroform as a valuable anesthetic.

One of the most memorable nights in the history of the world was when Simpson resolved to try personally the inhalation of chloroform. Sitting with his friends, Duncan and Keith, around a supper-table, he proposed a trial of the experiment. The three men, without the slightest adequate knowledge of what the result would be, inhaled the vapor. It was a brave, hazardous thing to do; but they did it. Almost instantly their conversation sparkled with unwonted scintillations of wit and humor; but it suddenly ceased, and a death-like silence reigned in the room. In a few moments the sound of falling bodies might have been heard; and then again all was silent. Simpson was the first to recover consciousness. He says that when he did so, he heard himself saying: "That is good." Then he saw Duncan lying on the floor, sound asleep and snoring; while Keith was struggling to regain the chair from which he had fallen when the chloroform did its work.

That was an historic scene, fraught with inestimable value to mankind. Here were three noble men, brave heroes, every one of them, experimenting at the conscious risk of their own lives, with a vapor respecting whose fatal qualities they knew not, in the hope of discovering a way by which poor suffering humanity might be spared from pain. They took the chance of sacrificing their own lives if necessary, for the good of mankind. Such acts of patient research, weary waiting, unselfishness, bravery, and heroism belong only to a profession in which saving of human life at the risk of losing one's own life is undertaken.

It appears that Simpson's mind had long worked on the great and perplexing problem. His daughter tells us that "very early in his student days he had so sickened at the suffering he witnessed in the operating-theater that he had shrunk from the scene, decided to abandon his medical studies and seek his way in the paths of law." This, however, he did not do. On the contrary he resolved "to fight a good fight" in the field upon which he had already entered, and he did, getting to himself an undying fame thereby, and conferring an immeasurable benefit upon mankind to the end of time.

Before leaving this part of our subject, it seems pertinent to call the attention of the enemies of vivisection to the splendid heroism and unselfishness which Wells, Morton, and Simpson displayed in making these hazardous experiments upon themselves, and not upon lower animals. This world would be far better off if these enemies to the true progress of surgery would take this noble object-lesson to heart, and cease their senseless tirade against vivisection, which has been as absolutely accessory to science as its benefits have been great. The only object and aim of vivisection is to save man from suffering, misery, and death. Shakespeare's thought that "it is sometimes necessary to be cruel in order to be kind" is true in this connection.

The topic of anesthesia must not be dismissed without a reference to Koller's discovery of local anesthesia by cocain, especially in ophthalmic surgery. The use of the spinal canal for medication, of which the injection of cocain for anesthesia is one of the administrations in vogue, was suggested by Corning in 1884. This particular form and method of anesthesia has been a contribution to surgery within the past quarter of a century, and has met the needs of a class of cases to which general anesthesia could not be applied.

As to the mortality of anesthetics, Poncet concludes that chloroform is more dangerous than ether, since Juillard's and Gurlt's statistics show one death in from 2000 to 3000 administrations of chloroform, and one death in from 13,000 to 14,000 of ether, while in nitrous oxid gas there are practically no deaths.

The influence of the introduction of anesthetics upon the progress of surgery can be best illustrated by a reference to the statistics of operations recorded in the Massachusetts General Hospital. Halsted has given the figures for 10 years before and 10 years after the discovery of anesthesia, which I quote. During the 10 years prior to the employment of anesthetics, there were only 385 operations performed in the Massachusetts General Hospital, or about 38 annually, or about 3 each month, or less than 1 a week. In the 10 years after the use of anesthetics began, and before the discovery of antiseptics, there were 1893 operations, or say 189 annually, or about 15 every month, or nearly 4 each week. If now the number of operations in the same hospital during the past 10 years is considered, it is found that they amount to 24,270, or about 2427 annually, 262 every month, and about 50 each week, while of those performed in the year of 1903, they number no less than 3109, or about 250 each month, or about 65 each week. What a tremendous advance upon the less than one operation each week of about half a century ago to the 65 each week at the present time in one hospital alone. It must be said, however, that this remarkable increase is largely due to the introduction of antiseptics, as well as anesthetics, in surgical practice. In other words, Hoffman has shown that the increase in surgical operations during the past half-century has been more than six times as great as the increase in hospital patients as determined by the Massachusetts General Hospital. So we are led to the second chief topic of this address.

2. *The Discovery and Practice of Antiseptics equal in Importance that of Anesthetics, and contribute almost as largely to the Progress and Development of Surgery during the Past Century.* This discovery, unlike that of anesthesia, belongs exclusively to no one nation. Pasteur, in France, discovered that putrefaction is due to the presence of bacteria in the air. Lister, in Scotland, applied the discovery to surgery. In Germany and in the United States a yet further application of the technic was made. Antiseptics, therefore, have been an evolution in which all well-progressed countries, notably Great Britain, have taken a part. Lord Lister's discovery will always stand as one of the great milestones in the advance of surgical science.

There are certain remarkable facts connected with the early surgery of this country which clearly foreshadowed the introduction of antiseptics. Absolute cleanliness was a characteristic feature of Mott's surgery. His personal toilet and the cleansing of every instrument before use indicated that he recognized perfect cleanliness as a *sine qua non* to surgical success; also the employment of animal ligatures in this country anticipated their general adoption as an essential part of antiseptic technic. Dorsey, as early as 1844, successfully ligatured large vessels with buckskin and catgut.

Hartshorne used parchment and Jameson proposed ligature from deerskin. All these factors, which now are recognized as an essential part of antiseptic surgery, were marked steps toward the perfect aseptic technic of to-day.

The general subject of antiseptics cannot be passed over without a just and generous recognition of Lord Lister's work. It is simply right to say that to him belongs the exclusive honor of having discovered antiseptic surgery. While at Glasgow, in his early professional life, Lord Lister became impressed with "the evils of putrefaction in surgery." What appalled him in his clinical observations was the difference of healing between a simple and compound fracture. In a compound fracture there was communication between the seat of fracture and the external air. This condition gave rise to suppuration, blood-poisoning, and death. In a simple fracture there was no communication between the seat of fracture and the external air, and the wound healed speedily without suppuration, blood-poisoning, or death. This striking behavior in the action of wounds led Lister to the discovery which has made his work imperishable, and has given an earthly immortality to his name. Mr. Lister believed that the blood in the wound underwent putrefaction in the same way as Pasteur had demonstrated that meat decomposed through exposure to the air. Lister's first endeavor was to overcome the evil by scrupulous cleanliness, just as Mott had done. But he quickly found that this method was inadequate to meet the need. Studying the subject, he immediately realized that Pasteur's theory was correct; that putrefaction was a fermentation produced by bacteria in the air; that these microörganisms could not develop *de novo*, in the putrefying substances; and that there was no such thing as spontaneous generation of bacteria. He also saw that when the bacteria in the air could be prevented from entering the wound, the wound would not suppurate nor give rise to blood-poisoning. He then asked himself the question, how can these bacteria be destroyed, or how can their fatal entrance into a wound be prevented? In other words, how could we kill the bacteria and yet not harm the patient?

This was the problem and proposition. Its solution is antiseptic surgery. Lister had heard of carbolic acid as a deodorizer. As such he applied it, undiluted, to a compound fracture, with repeated renewals. Watching with intense interest the application, he was overjoyed to see that suppuration was almost entirely prevented and so all fear of blood-poisoning and death removed.

This was, practically, the discovery of antiseptics. A method for preventing putrefaction was found, and in consequence aseptic healing by gradual evolution and by modern improvements followed. No one can measure the vast influence which this wonderful discovery has had upon the human race. It has eliminated local pain in a wound, it has prevented general fever, it has made possible many new life-saving operations, it has saved millions of lives.

The influence of antiseptics upon the increase of surgical operations, and the decrease of mortality attending them, is difficult to estimate. Suffice it to say, by way of illustration, that in the Boston City Hospital prior to the introduction of antiseptics there were, in 1878, according to Halsted's statement, only 132 operations performed, while in the same hospital, in 1903, there were 2719. In the New York Hospital, in 1878, there were 142 operations, in 1903, there were 1680. How different and justly so the prevailing idea of the day as regards the operative part of surgery. Prior to the past century, operations were looked upon as a tacit confession of failure, and such they commonly were. Tó-day, they are properly recognized as the grand triumph of a new science. These facts tell the story of the progress of surgery more forcibly and eloquently than could be done by any spoken discourse, no matter how carefully prepared.

3. *The Discovery and Practice of Modern and Surgical Therapeutics and of New Diagnostic Aids.* This part of our subject embraces all the non-operative methods of treatment of surgical affections which have been devised during the past century. It is obvious that within the limits of this address mere mention only can be made of the various remedial agencies and the general results which have been obtained by their application.

The Röntgen rays were discovered about 1896, and the civilized world was startled by a discovery which ranks after anesthetics and antiseptics as one of the greatest advances in the science of surgery. Röntgen demonstrated that the Röntgen rays would pass through the human body and throw a shadow picture on a photographic plate. In other words, that the rays had the power to pass through substances which were opaque to ordinary rays of light. Bullets can be seen and located in the body, and bones can be distinctly outlined, because they are denser than the soft tissues. Fractures and diseases of the bones, dislocations and diseases of joints, as well as foreign bodies in the economy, can be observed. Tuberculous processes in the lungs can be distinguished, and the heart can be seen actually pulsating. Gall-stones can be made out in the gall-bladder, and calculi can be detected in the pelvis of the kidney and in the urinary bladder. Sarcoma, myelitis, syphilitic osteitis, bone abscess, periosteal and central origin of bone tumors can be diagnosticated. Carcinoma, tuberculosis, osteoarthritis, osteoporosis can be made out with distinctness. Brain tumors, notably gumma, Hodgkin's disease, aneurism of the large vessels, and glandular enlargements and growths in the mediastinum can be demonstrated.

The Röntgen rays have also been used with a view to the cure of certain malignant diseases, notably cancer of the skin and sarcoma, especially when the disease cannot be treated by ordinary means. It does not appear to have been of any special value in other forms of cancer located in the organs of the body. The Röntgen ray has also been employed as a depilatory, also to bring about atrophy of the glands of the skin and to relieve pain. The Röntgen ray also is used to cure pseudoleukemia and splenomedullary leukemia, rodent ulcer, lupus vulgaris, and chronic eczema.

Great credit belongs to our distinguished chairman for the magnificent work which he has performed in the application of the Röntgen ray to surgery, and his writings upon this subject are worthy of close study.

The *Finsen light* is a discovery which was made about 1897, by means of which certain forms of cutaneous disease of an infective origin, notably lupus, have been cured. This result is accomplished by means of a light which can be employed without accompanying heat, and which causes an inflammation of moderate intensity upon the skin. Sunlight fails to destroy bacteria, owing to the presence of heat, while the Finsen light, deprived of heat, effects a cure.

In 1878, Blunt and Downes proved the efficacy of chemic rays of light to kill bacteria. Finsen demonstrated that the action of light was increased if it be applied through rock-crystal lenses, and the heat absorbed by passing it through a violet-colored liquid and water, while the part of the body to be treated is made anemic by pressure. Finsen apparatus increased the efficacy of the violet or chemic rays, and absorbed red or heat rays. The effect of light upon bacteria is slow in its operation, but its rapidity is increased by concentration, by means of mirrors or by lenses. The heat-rays, such as ultra-red, red, orange, or yellow, must be eliminated, as they burn the tissues, while the blue or violet rays destroy the bacteria. The arc electric light comes next, and is now often used because it can be obtained at all times. The incandescent light is of no value, owing to the fact that it possesses too few chemic rays. The electric light requires a special apparatus for its use, since its rays are divergent and not parallel, as is the case in the sun's rays. Professor Pupin says that the time is not far distant when a new method of producing light of short wave-length will be perfected, which will be far more powerful than the Finsen light. The shortcomings of the present method of producing light of great actinic power consist principally in the absorption of this light by the glass of the vacuum tubes in which it is produced. Within the last year a method has been discovered of fusing quartz, and blowing it out by means of the oxyhydrogen flame into bulbs, which are used for electric vacuum tubes. Quartz, as is well known, absorbs light of short wave-length to a very slight extent, and it is the light of short wave-length which is employed at the present time for therapeutic purposes. When this discovery is applied to surgery, the field of usefulness of light as a remedial agent will be greatly enhanced, and without doubt many new diseases will be relieved that the present Finsen light fails to cure. The results of treatment of lupus by the Finsen light are interesting. In 456 cases in which the treatment had been completed at the end of 1900, no fewer than 130 are known to be free from recurrence for from one to five years. In the rest of the cases the period of cure is too short to establish any reliable data. In 44 cases of lupus erythematosus, 14 were reported cured and 15 improved. In 49 cases of alopecia areata, 30 were reported cured. In 24 cases of rodent ulcer and cancroid, with 11 favorable results. In 25 cases of acne vulgaris, 13 were cured. These statements give an approximate idea of what has been accomplished in a short time by Finsen light, and, without doubt, improvement in the technic will result in even a greater number of percentages of cure.

Radium is a new element which was discovered in 1899 by Madame and M. Curie. The term "radium" is derived from the Latin word *radius*, meaning a ray. At the present time there is great interest in the question of the therapeutic use of this metal, but sufficient time has not elapsed to determine its value.

Radium is a new therapeutic agent which has recently been used in surgery, and furnishes a new illustration of the development of the science. Radium as a therapeutic possibility is little understood, but about which much has been written. The public press has been flooded with sensational articles about radium, while the medical press has been conspicuous for the meager accounts of its therapeutic uses.

The action of radium depends upon its "spontaneous source of energy" upon living tissues. The action of radium upon the tissues is very similar to the Röntgen rays, and its use is indicated in those cases in which the Röntgen ray is applicable. Radium as a therapeutic agent depends upon its radiations, which are of three kinds, and have been designated by the terms Alpha rays, Beta rays, and Gamma rays. The Alpha rays consist of a current of electric charge that contains an amount of energy far greater than the Beta rays or the Gamma rays. The velocity of the Alpha rays is said to be 20,000 miles per second. Ninety-nine per cent of the energy of radium is in the Alpha rays. The Beta rays consist of a negatively charged stream of particles very similar to the cathode. The Gamma rays travel with tremendous velocity and are similar to the Röntgen ray from a hard tube. The Alpha rays have very slight actinic properties, while the Beta and Röntgen rays are highly actinic, and are therefore the rays used in therapeutics. Beta rays do not penetrate the tissues deeper than half an inch, while the Röntgen rays from the pure radium pass through the body. Radium gives off heat and a gas called helium, but these properties have no influence in the therapeutic action of radium. Radium destroys bacteria and affects the metabolism of cells and is used in the treatment of certain skin affections, notably lupus, keloid, nevi, rodent ulcer, epithelioma, carcinoma, and sarcoma. The action is similar to the Röntgen rays, but the chief advantage of radium consists in a precise estimate of the dosage, while the Röntgen ray, on the other hand, is a more powerful energy, but it is difficult to estimate its exact strength.

Electricity has had great influence in the development of surgery during the past century. It has been employed in many ways, both as a diagnostic aid and as a means of cure. The electric light is used as a means of diagnosis to explore the hidden parts of the body such as the throat, larynx, esophagus, and stomach, also the bladder and the intestinal canal. Perhaps one of the most useful purposes to which electricity has been employed in a diagnostic way is illustated by the cystoscope by means of which the interior of the bladder can be explored with a view of determining the exact nature of the lesion, the shape and anatomic relations of a growth, or the presence of a foreign body in the hollow and heretofore impenetrable viscus. The stomach also has been explored with a view to determine the nature of the lesion. It is also used to test the contractility of muscles which should respond quickly to the faradic current if the nerve is diseased. In this way the surgeon can diagnosticate functional or organic disease of the nerve by the behavior of the muscles when the electric current is applied. The electric current is used in surgery as a curative means in the removal of small malignant growths and nevi, to arrest primary hemorrhage in places when the ligature is inapplicable, or secondary hemorrhage where compression is not admissible. In the form of an *écraseur*, electricity is used to remove pedunculated tumors, to cauterize long sinuses, to arrest suppuration in the eyeball, to sterilize the pedicle after appendectomy, ovariotomy, or hysterectomy, to cause coagulation of blood in the treatment of aneurism, to overcome obstruction in the eustachian tube, to find bullets imbedded in the human body, by a probe which was invented by Girdner of New York, to stimulate muscles and nerves, to improve the circulation of the blood, and even to relieve severe pain.

Serum therapy is a newly discovered method for the treatment of certain surgical diseases, among which may be mentioned hydrophobia, tetanus, acute phlegmonous inflammations, anthrax, and other infectious processes. The history and development of surgery during the last quarter of a century would be incomplete without a reference to the inoculation method to prevent certain surgical diseases. The principle involved in this system is the one enunciated by Pasteur, to whom the world owes an everlasting debt of gratitude.

In 1880, Pasteur announced to the French Academy of Science that he had discovered a method of inoculation, by means of which he could reduce the virulence of a disease caused by a special germ. An attenuated virus of the germ-disease was inoculated into the system of a susceptible animal, and this infection would give rise to only a mild attack of the disease. The attenuation of the virus, as Pasteur termed it, was accomplished by cultivation of the special germ in certain mediums exposed to the air. His research up to this time was limited to chicken-cholera; but he announced that in the future he believed that the great principle of inoculation would extend to other diseases. In 1881 he proved to the world the correctness of this view by announcing his cure of anthrax, that fatal malady affecting sheep and cattle. The world was skeptical of his discovery, and the president of the Agricultural Society of France urged Pasteur to make a public test of his cure. To this proposition Pasteur, in the true spirit of scientific faith, assented, because he was fully convinced of the truth of his theory. Fifty sheep were supplied by the president of the Agricultural Society for the test. To this flock Pasteur requested that 10 cattle be added and 2 goats be substituted for 2 sheep, with the understanding that failure in his experiment with cattle and goats must not invalidate the test, since he had never carried on experiments with cattle or goats. The acceptance of this challenge by Pasteur was a brave act; because he knew if he failed in this public experiment the world would denounce and deride him. The inoculations of the attenuated virus of anthrax were then made on 24 sheep, one goat, and five cattle, at certain intervals upon three successive occasions. After a proper time had elapsed the 60 animals were inoculated with a culture of the anthrax microbe. Forty-eight hours after this injection of the full-strength virus into all the animals, the public gathered to witness the success or failure of this most wonderful experiment in the scientific world. The sight that the eyes of the vast crowd beheld beggars description. In the paddock were seen dead or moribund every animal that had not been previously inoculated with the attenuated virus. In this same paddock were seen the remaining animals that were inoculated with the attenuated virus walking about apparently in perfect health. This paddock formed a veritable arena in which was witnessed the greatest battle that science has ever fought. The victory was complete, unequivocal, and overwhelming. This successful experiment established a new epoch, and this new principle was soon applied to certain human diseases.

In 1885 Pasteur proved the value of this method in the treatment of hydrophobia. In this latter disease the virus of rabies was inoculated into guinea-pigs or rabbits, and an attenuated virus was made from the spinal cord of these inoculated animals. The mortality of hydrophobia by Pasteur's treatment, by Celli, of Rome, has been only 5 %, since 1899, at which time the institute was built and organized, and during these four years 2000 patients have been treated with the serum.

The value of serum therapy is shown by a reference to the work of the lamented Walter Reed, of the United States Army, who discovered a treatment for yellow fever, a disease which destroyed over 80,000 persons in this country during the past century. To-day this scourge has been wiped from the face of the earth. The bubonic plague, the most frightful disease that could visit a country, created panics among the people in former years; but now, owing to the efficacy of serum therapy, its entrance into this country creates only a passing comment. Even in New York the disease was observed at quarantine, and was stamped out immediately. Thompson predicts before long that the bubonic plague, which is now practically confined to the valley of the Euphrates, will be annihilated from even that locality, as well as cholera from the valley of the Ganges. Haffkine's serum for the treatment of this bubonic plague reduced the susceptibility of those exposed to the infection 75 %, and the mortality by 90 %.

Gilman Thompson says that "thirty years of bacteriology in all of its applications have done more for mankind than all the medical research that has preceded. In an estimate made by Alfred Russell Wallace of 25 discoveries of world-wide importance made during the nineteenth century, a fifth were contributed by medical science, and all but one of these were made during the last half of the century. Two more have been greatly influenced by medical science, viz., the theory of the antiquity of man and the doctrine of organic evolution. Yet we have not wholly emerged from the shadows of the Middle Ages, for have we not still among us those who fain would abolish such experiments as have made possible discoveries like those of vaccine, antitoxin, and antihydrophobic inoculations, even as there are those in Persia who would mob physicians seeking to check the spread of cholera?"

Tetanus is a surgical disease which baffled the skill of physicians for centuries. Recently it has been treated with very encouraging results by means of antitoxin. This method of serum therapy, together with the application of antiseptic surgery, has yielded results that offer a striking illustration of the onward march of surgery. In olden times the mortality in tetanus, according to Lambert was 80 % for acute cases, 40 % for chronic cases, and 60 % as an average for all cases. The mortality in tetanus, treated by antitoxin and by antiseptic surgery, was about 61 % for acute cases, and 5 % for chronic cases, and 30 % for all cases.

From these statistics it is evident that antitoxin has reduced the mortality half, and if the antitoxin were properly used, the mortality would be much less than half. The reasons why antitoxin has no better statistics at the present time are because the antitoxin has not been pure or long enough continued, or not in sufficient doses, or too late in its administration. If properly used, the reduction in mortality would be striking, and from now on the results will be entirely different. Antitoxin has its widest field of usefulness as an immunizing agent. All surgeons agree that it would not be justifiable to immunize a patient on the vague supposition that tetanus might develop. The use of the antitoxin as a prophylactic measure is consequently limited to those cases where the wound has been inflicted in such a manner as to allow garden-earth, plaster from walls, or manured soil to come in contact with it, or where the traumatism has been caused by a rusty nail upon which the bacilli are discovered, or in a given locality where tetanus is prevalent, or where the wound is a lacerated one with entrance of foreign bodies into it. In these cases Murphy states that the injection of antitoxin has reduced the mortality 50 %.

Bazy, a French surgeon, had four fatal cases of tetanus in his practice in one year, and subsequently began injecting 20 cc. of serum into all patients who suffered from lacerated wounds, into which extraneous matter had of necessity entered. Since he adopted this practice, tetanus has not followed in those cases in which a strong probability existed that this dreaded disease might develop. Lambert mentions that Nocard, in veterinary surgery, immunized 375 animals, and in no single case did tetanus develop, while he had 55 cases of the disease in non-immunized animals in the same environment. Antitoxin does not affect in any way the life of the bacilli of tetanus, or the spores. Both the bacilli and their spores, when they penetrate the tissues by a wound, live for days and weeks. In these cases, when antitoxin is given for the purpose of preventing the symptoms which would be caused by the toxins during the first few days, it will destroy the action of the toxins. If, however, some of the spores remain quiescent, they may only develop into bacilli at a time when the antitoxin has been eliminated, and if they then develop into bacilli the toxins produced will be absorbed, and cause symptoms just as if they had received no immunization dose of antitoxin. For this reason, the immunizing dose should be repeated after the first week, and even after the third week.

Antitoxin as a remedy during the progress of the disease has an important influence upon tetanus; but not to the same extent as when employed for immunizing purposes. Welch believes that the longer the period of incubation, the better will be the results from the use of antitoxin, and that this remedy is of little value with a short incubation period, that is, less than seven days. When antitoxin is used under these circumstances, it should be continued long after the symptoms of tetanus have subsided. Lambert has also called attention to a most important point in the treatment of tetanus, and that is, the great care the surgeon should exercise after all symptoms have disappeared. For example, absolute quiet should be insisted upon long after the patient has become convalescent, since he knows of five deaths recently in New York City where the patients were awakened suddenly out of a sound sleep, and a convulsion was brought on from which the patients died.

Antiseptic surgery plays an important rôle in the treatment of tetanus, since it has been shown that in the majority of cases of tetanus the infection proceeds from the development of the spores rather than from the bacilli. It has also been demonstrated that the spores develop better under special circumstances of a mixed infection, and, therefore, all tetanus wounds should be made aseptic in order to destroy the microbes of suppuration, notably the streptococci and the staphylococci. It often happens that the wound is situated on an extremity, notably on the finger or toe, and the question arises as to the propriety of amputation of the affected part. This operation is of no avail unless the sacrifice is made immediately after the infliction of the injury, but it is indicated if the wound cannot be thoroughly disinfected. It is better to live without a finger or toe, or even a leg, than to run the risk of tetanus with its attendant suffering, which leads in the acute cases so often to death. The small punctured wounds, which may seem insignificant, should be incised deeply, thoroughly cleansed, and then properly drained. The toxins of tetanus are chiefly eliminated by diuresis. To best utilize this channel of elimination the imbibition of large quantities of fluid is indicated. The saliva has also been said to be a channel of elimination. The function of the skin has not been proved to be of any avail in eliminating the poison. The employment of anodynes forms also a prominent part of the treatment. This step, therefore, should not be overlooked, since it is clearly proved that much suffering can be relieved by certain drugs. Among the drugs that are found to be most useful are chloroform, morphine, chloral, bromides, physostigmin, antimony, and nitrate of amyl. Chloroform is a most valuable remedy, because it relieves the intense suffering and diminishes the intensity of the spasm and also prevents suffocation. This agent must be used with every precaution and with every stimulant present, and ready for immediate use. Statistics show that when chloroform was employed in the treatment of tetanus, the mortality was 10 per cent less than in the cases when the drug was not employed.

Thus it is evident that the use of antitoxin, the employment of antiseptic surgery, the administration of certain anodynes and the enforcement of quiet to avoid reflex disturbances, comprise a plan of treatment which will offer brilliant results in the cure of this terrible malady. The success of this treatment in tetanus alone is a monument of the progress which surgery has made during the past quarter of a century.

The antitoxin treatment of diphtheria affords the most forcible illustration of the value of serum therapy in the treatment of infectious diseases. This disease does not, strictly speaking, belong exclusively to surgery; but it affords an opportunity to show the results of the use of antitoxin, and it often happens that the disease may require surgery for its relief. From the statistics of the Health Board of New York City prior to January 1, 1895, the mortality was as high as 64%, and in 1902, as a result of the use of antitoxin, mortality was reduced to 9.5%. From a period of 5 years, from 1888 to 1894, the mortality was from 64% to 44%, and the following 4 years, from 1895 to 1898, the mortality dropped to 12%. In 1902 the mortality was reduced to 10.9 %. In another series the cases were also not selected. They were collected from hospitals, asylums, private residences, and many of them were moribund at the time of the use of the antitoxin, and the mortality was less than 8 %, as contrasted with 64% to 44% 20 years ago, or before antitoxin was employed. In 1903 the improvement was still greater, since in 1208 cases of diphtheria only 72 died, thus giving a mortality of only 5.9 %. If the 26 moribund cases were deducted, the mortality is only 3.8%. There remains no longer any doubt as to the value of serum therapy in this disease, and if these results can be taken as prophetic of the result of serum therapy in other infective diseases a new era has dawned upon the civilized world. Billings has called attention to one fact, and that is the necessity of the early administration of the antitoxin, since in 1702 cases injected on the first day, only 85 patients died including the moribund cases; the mortality was only 4.9%. Finally, in 1610 cases collected from 12 physicians in private practice, and not including the moribund cases seen in consultation, there were 24 deaths, or a mortality of only 1.5%. An antitoxin has been made by Calmette, who worked in the Pasteur Institute, to prevent death after the bites of venomous serpents. This antitoxin has already afforded immunity to thousands of persons who had been poisoned by the bite of venomous reptiles in India and Australia.

The antitoxin treatment of snake-bite was discovered by Vital, of Brazil. He made some extensive experiments with antitoxin at the institute over which he had charge. This serum was better than the control tests with Calmette's anti-venom serum. Vital called the serum anti-ophidic, and he reported 21 cases of bite of venomous reptiles with recovery, without any appreciable clinical symptoms. The strength of this anti-ophidic serum is shown by the fact that even a fraction of a milligram of the snake-venom causes severe symptoms to appear when injected into lower animals. In three of the 21 cases, the symptoms appeared almost immediately after the bite of the snake, and were most pronounced in type. In these three cases, however, 20 cc. to 60 cc. of the anti-ophidic was injected and recovery took place, notwithstanding two hours had elapsed in one case, and three hours in another case. Vital has also prepared a special serum for the bite of rattlesnakes.

In India, 22,000 persons and 60,000 cattle die each year from the bites of the poisonous ophidia. Many of these deaths can now be prevented by inoculation of the anti-venene. In tuberculosis the mortality has been reduced 50%. Koch's wonderful discovery is an enduring monument to his greatness. In Germany alone 90,000 persons die annually from tuberculosis. This gives us an idea of the far-reaching influence of Koch's marvelous discovery.

Blood analysis has had much to do with the development of surgery, and affords a most valuable diagnostic aid. Without this contribution from the science of hematology the development of surgery would never have reached its present state. This is not the place to enter upon any discussion of blood analysis except as it pertains to surgical diagnosis, by means of which the broad field of operative surgery has been enlarged. In speaking of blood analysis a reference only will be made to the influence it has upon operative surgery. Blood analysis makes certain the diagnosis in some surgical diseases, it aids in the diagnosis of other diseases, and it helps to diagnosticate a condition, where from unconsciousness, inability to speak, insanity, or malingering, a history is unattainable. The chief points to ascertain are the number of erythrocytes, the leukocytes, the ratio of one to the other, the number of blood plaques, and the ratio to each other, the size, form, and contents of the blood-cells, the amount of hemoglobin and of fibrin, the specific gravity of the blood, and bacteria contained in it. The erythrocytes or red blood globules normally exist in the blood in the proportion of about 5,500,000 in a cubic millimeter. The term oligocythemia indicates a deficiency in the number of red blood globules, or a diminution of their relative proportion. The term poikilocytosis indicates an irregularity in the shape and size of the globules, and an increase in the red blood globules is called polycythemia. Now oligocythemia is observed in hemorrhages, anemia, etc. Polycythemia is observed in cases, where there is a loss of fluid from the blood as in cholera, severe diarrhea, etc. The leukocytes or white blood globules normally exist in the blood in the proportion of about 7500 in a cubic millimeter. An increase of 1500 or more in the number of the white cells indicates a condition known as leukocytosis.

Now, a normal leukocytosis is observed in health after meals, during pregnancy, following violent exercise, a cold bath, and massage. An abnormal leukocytosis is observed in such diseases as erysipelas, osteomyelitis, suppuration, malignant tumors, and in pneumonia. The term leukemia indicates a permanent leukocytosis. In the differential diagnosis of surgical affections, blood analysis is of great assistance. For example, in shock from hemorrhage there is oligocythemia. In shock from concussion or compression of the brain, there is no decrease in red blood cells. In appendicitis and pus tubes, there is a leukocytosis, while in floating kidney, ovarian neuralgia, gall-stones, renal and intestinal colic, it is absent.

In meningitis, in cerebral abscess and cerebral hemorrhage, there is leukocytosis, while in other intracranial lesions it is absent, In all forms of sepsis, leukocytosis is present. Blood plaques normally exist in the blood in the proportion of 200,000 cm. to 500,000 cm. In disease, the plaques are increased.

Hemoglobin normally exists in the blood in about 90%, and below 20% is the minimum in life. The relation of hemoglobin to the erythrocytes and the rapidity with which it regenerates after injuries, surgical operations collapse, and hemorrhages, enables the surgeon to determine the prognosis. Syphilis and cancer retard the regeneration of hemoglobin, while tuberculosis, curious to state, increases the regeneration. In operation for removal of cancer, for example, the amount and rapidity of regeneration of the hemoglobin enables the surgeon to determine whether complete removal of the malignant tumor has been accomplished, and whether the rapidity is sufficient to justify the conclusion that perfect health can be reinstated.

4. *The Improvement of Old and the Discovery of New Operations with their Mortality.* It is obvious that a consideration of this part of the subject can only embrace a cursory review of the field of operative surgery. No attempt will be made to describe in detail an operative procedure. A mere reference to the improvements in old operations and the discovery of new operations will be made as affording tangible evidence of what surgery has accomplished for mankind. The operations that have been discovered and performed within the past 100 years will be mentioned, and an endeavor will be made to show to what extent the science of surgery has been a benefaction to the human race. In order to demonstrate this proposition, it is necessary to record the date of the first performance

of each prominent operation, and then to show what result has been accomplished since its introduction. In this way an idea can be obtained of the value of each great operation, and the advance which each has made toward saving life. A review of this kind naturally is devoid of popular interest, but at the same time these important factors are worthy of record and study. In this way only can the true progress of surgery be measured, since the operations performed prior to the past century are insignificant and unimportant. It is only by a study of the operations of the past century that the magnitude and usefulness of modern surgery become impressive and apparent. If what has been accomplished during the nineteenth century be taken from the sum total of knowledge of surgery, nothing will be left to entitle surgery to a recognition among the sciences. The work accomplished with the century, however, as a study entitles surgery to a prominent place among the sciences.

The important operations will be considered in the following order: Those belonging to the cranial, thoracic, and abdominal cavities, and finally those of a miscellaneous nature.

External to the cranial cavity, the operation for the cure of racemose arterial angioma, aneurisms of the scalp, sinus pericranii, dermoid cysts, sarcoma, and carcinoma, are among the recent operations that indicate the extension of surgery in this department. The improvement in the technic of the operation for compound fractures of the skull, fractures of the base, encephalocele, and within the cranial cavity, the operations for the relief of hydrocephalus, compression of the brain, ligation of the middle meningeal artery, are worthy of mention, as denoting the progress which surgery has made within recent years. Abscess of the brain has been recently treated with success. Delvoie cites 21 cases of trephining for acute cortical abscess, with 15 recoveries, and 33 operations for chronic deep-seated abscess, with 19 recoveries. In cerebral abscesses secondary to otitis media, Ropke reports 142 cases, 59 of which recovered, and 40% were permanently cured. Frontal abscesses of nasal origin have been operated upon with brilliant success. This life-saving operation which has resulted in cure, until recently hopeless, indicates the progress of surgery. In thrombosis of the intracranial sinuses with operation, results have been obtained. Thus Macewen had only 8 fatal cases in 28 cases. For the cure of infective thrombosis, all of which die without surgical intervention, this is a remarkable showing for this new operation.

Intracranial tension has very recently become a new indication for operative interference. This operation affords relief in a class of cases that heretofore were fatal. This operation is a contribution of modern surgery, and is another milestone which marks the progress of the science of surgery The recent advances in clinical medicine and clinical microscopy have opened up the heretofore unexplored field for operative interference. Cases of coma with no external injury of the skull have heretofore been treated by the expectant plan, with almost uniformly fatal results. Surgery owes much to these two departments of medicine for valuable knowledge upon a subject which is comparatively new, and which offers an additional field for operative work. Intracranial tension is a condition which a study of modern pathology has shown calls for surgical interference. Intracranial hemorrhage is one of the most frequent causes of intracranial pressure. It may also be caused by bone, pus, and foreign body. In order clearly to understand the theory of intracranial pressure, it is necessary to bear in mind two facts: (1) that the brain itself is incompressible; and (2) that the cranial cavity itself is incapable of expansion, therefore, the pressure of a clot of blood or a fragment of bone, or a collection of pus, or any foreign body, must be accommodated in the limited space in which the brain is lodged. If the foreign body is of sufficient size to fill the intracranial space by a twelfth, death results.

The treatment of intracranial tension is a new subject, and one which I have of late given special study. I am convinced that operative treatment is indicated in many of these cases. I have employed this measure with most gratifying success. The indications for operative interference are in some cases perfectly clear, while in others the phenomena present would not justify resort to so severe a measure. The greatest difficulty is to determine what the line of demarkation is between the cases that demand trephining or lumbar puncture, and those in which the plan of expectancy can be adopted.

These cases of intracranial tension can be divided into two classes as regards operative interference. The first class includes those in which intracranial tension is sufficient to produce profound coma. Operation will save patients included in the first class that uniformly died under the expectant plan of treatment. Operation will save the patients embraced in the second class when the symptoms are gradually increased in severity. In regard to the indications for operation to relieve intracranial tension in those cases included in the second class in which coma is not present, the problem is difficult of solution. I have been guided as to the operation by the condition of the patient after a study of the symptoms from hour to hour and from day to day. If the arterial pressure arises to a point and remains stationary, and the vasomotor system does not fail, even with a well-pronounced vagi disturbance, no operative procedure was practiced, and recovery has taken place. In addition to the symptom of increase of arterial pressure, the blood-count must be studied, the eye-grounds examined, the urine tested, the reflexes studied, the disturbances of cranial nerves noted, and all other phenomena investigated. If the pressure is not daily increasing, and the leukocytosis not rising, the red blood cells not increasing, and the urine not becoming glycosuric, the hebetude not emerging into coma, and the cephalalgia not increasing, delay in operative interference is indicated. If all the above-mentioned symptoms from a stationary point begin to increase, operative interference is called for to save the patient's life. If on the other hand, from this stationary point, all the symptoms show an improvement, operation can be deferred at least for the present, if not permanently.

The operation for relief of insanity is worthy of consideration. Surgery has accomplished great victories in the restoration of reason in the insane, when the lesion was due to traumatism. A little over a hundred years ago the management of the insane was most revolting and brutal. In Europe the treatment of the poor outcasts was a blot upon the civilization of the world. Imagine these poor wretched creatures consigned to dungeons and manacled by chains for years. In these dark prisons, the insane, considered as demons, were kept in irons amid squalor and filth. It has been stated that the iron tether was so short that these poor unfortunate victims could not even stand upright and were held for years by chains riveted around the neck or waist. The humane treatment of those poor unfortunate people began about a century ago and great credit is due to neurologists who have rescued these sufferers by throwing aside their manacles, by restoring to them their liberty, and by proffering them treatment. Men like Tuke and Pinel and Rush took the initiative in this great reformation. As soon as a rational, humane, kind treatment was instituted, it became evident here and there that among these insane, epileptic demons as they were called, there were some who could be relieved and sometimes cured. Surgery has been employed for this purpose, and some of the results are almost miraculous.

In the course of the development of surgery, operations have been devised for the relief of insanity where the etiology was due to pelvic disease. In DaCosta's monograph it is mentioned that Hobbs operated on 116 cases of pelvic disease in the insane, with a mortality of the operation less than 2 %, and recovery from the insanity in 51 %, and great improvement in 7 %. "In the group of non-inflammatory troubles, tearing of the perineum, uterine displacements, tumors, etc., 25.5 % regained mental health, and 31 % improved."

In the surgery of the heart great progress has been made. Bimanual massage of this organ has been successfully resorted to by Cohen in a case of collapse following chloroform narcosis and during laparotomy. In a case described by him: "Artificial respiration for two minutes having no effect, he introduced his hand into the abdominal cavity, pushed along the anterior abdominal wall until the diaphragm was reached, and placing the hand, palm upward, in about the position the heart would normally be, that organ was freely grasped through intervening diaphragm. There was an entire absence of heart action. Placing the right hand over the precordial region, externally, he now plainly palpated the heart as it lay between his hands, and began rhythmic compression, using both hands at a rate of about sixty a minute. After about thirty seconds a slight beat was felt by the left hand. The heart now began to beat slowly, gradually increasing in strength and rapidity until at the end of a minute the beats registered about eighty, and respiration began to be partially reëstablished. About two minutes after this, respiration was normal, pulse 80, and shock being apparently recovered from, the anesthetic was changed to ether, and the operation finished in about thirty minutes, with recovery of patient."

For the relief of pericardial adhesions, a new operation has been devised by Peterson and Simon. This operation is analogous to Estlander's operation for pleuritic adhesions. The operation consisted in a resection of a portion of several ribs, and in some cases a part of the sternum. Murphy cites the fact that of 38 cases of stab-wound of the heart, 90 % were penetrating, and only 19 % were immediately fatal, thus leaving 81 % of the cases amenable to surgical treatment. This new operation, the outgrowth of modern surgery, will afford a new field for this science to save human life in a class of cases heretofore fatal.

In addition to the surgery of the heart, there are many other operations of the chest that deserve mention as indicating the progress which surgery has made within the past century. In surgery of the chest the wounds of the pleura and lung have been successfully treated since the introduction of antiseptic surgery. Abscesses of the mediastinum, caries, and necrosis of the ribs and sternum, tumors of the chest-wall, actinomycosis, and other infective processes, removal of fluid from the pleural and pericardial cavities, are among the recognized operations of the day.

Wounds of the heart during the past century, and especially during the past 10 years, have been treated surgically with remarkable success. Stewart reports that Roberts, in 1881, suggested the propriety of suturing these wounds. Tillmann believed in the hopelessness of this procedure, yet in 1897, Rehn published the first successful case of cardiorrhaphy in man. Stewart likewise has operated with success, and he has collected 60 cases with the brilliant result of 38.3 % of recoveries.

In the surgery of the lung advance has been made within the last quarter of a century. The diseases of the lung which have become amenable to surgical treatment are tumors, tuberculosis, abscess, gangrene, hydatid cysts, actinomycosis, and bronchiectasis. Murphy has collected 47 cases of tuberculosis; 26 patients were improved and

19 died; 8 cases of actinomycosis, in which the patients recovered; 96 operations for pulmonary abscess, with 80% of recoveries; 122 cases of pulmonary gangrene, with 66% of recoveries; 57 operations on bronchiectasis, with 60% of recoveries, but only half permanently cured; 79 cases of hydatid cysts of the lung, with about 90% of recoveries. In some 400 cases of pneumotomy collected from various sources by Murphy there have been about 300 recoveries, or about 75%. This is a most remarkable result in a department of surgery that has developed within a few years, and includes a class of cases that were formerly practically hopeless. Much credit is due to Murphy for his work as a pioneer in thoracic surgery. Perhaps one of the most interesting operations in connection with pulmonary surgery refers to tuberculosis of the lungs. In reference to excision of tuberculous foci, Whitacre has shown that in nearly 98% the operation is "impossible and irrational." In only 2% of the cases can surgery afford relief, and in these cases the foci are located in the apices of the lung. It is thus evident that there is little to be expected in the future as regards pulmonary surgery as it refers to tuberculosis, since careful investigation has demonstrated the fact that, as a rule, the tuberculous foci are not accessible to the surgeon. Before dismissing this subject the nitrogen compression method introduced by Murphy deserves recognition. The object of this method is to compress the diseased lung by gas, thereby restraining its movement to cause a mechanical obliteration of the cavity and the limitation of the already existing focus, to favor fibrosis, thereby closing in the avenues of dissemination to afford rest to the affected part in the same manner as a splint to a fractured bone. In certain judiciously selected cases this method is applicable.

In October, 1842, Sayre made a free incision in the chest in a case of empyema, and the patient made a good recovery. Forty-eight years ago Sayre raised the inquiry, "In the empyema of a tuberculous patient from the rupture of an abscess into the pleura, should we not be justified in tapping as soon as discovered?" In 1850, Dr. Henry Bowditch suggested and practiced paracentesis thoracis. Wyman, unaware of Bowditch's operation, performed the same operation. For a long time in this country, as well as in Europe, paracentesis thoracis was condemned; but at last the operation has advanced to the stage of full acceptance by all surgeons. It is almost impossible to estimate the number of lives saved by this operation, but the number is very great, and this operation forms an enduring monument to the fame of American surgery.

Surgery of the stomach has claimed attention only for the past quarter of a century, for previous to that time it was practically unknown. The unsatisfactory state of the surgery of the stomach previous to 1875 is best illustrated by a reference to statistics. It has been shown that of 28 operations attempted upon the stomach, there were 28 deaths, or a mortality of 100 %. From 1875 to 1884, improvement took place in that 163 operations were performed with 133 deaths, or nearly 82 % mortality.

The reduction of the mortality of 100 % to 82 % was a gain in the right direction; but it left much to be desired. The rapid strides which scientific surgery has made in the operations upon the stomach forcibly illustrate what can be expected in the future in this department of surgery. There are at present about 12 recognized operations upon the stomach, and in 7 of these there is practically no mortality, while in the remaining 5 it has been reduced to about 25 %. Keen predicts as technic improves the mortality in the most difficult operations ought not to be higher than 10 %.

I should predict, from an examination of late statistics, that even less than 10 % has already been accomplished, and in the future the mortality will be still lower. Mayo has shown that in an investigation of over 900 operations upon the organs contained in the upper abdominal zone there existed a relationship between gall-bladder and ducts, the duodenum, the pancreas, and stomach. In other words, that the continuity of tissue like the mucous membrane makes the disease of one organ a menace to the others. Mayo also believes that the duodenum, on account of its situation, acts as a buffer, and is involved secondarily in about an equal proportion of cases from gall-bladder disease and gastric ulcer, in the same way Mayo pointed out that diseases of the pancreas were secondary to gall-stone diseases.

Cardiospasm, in which there is difficulty in deglutition from a spasm of the muscles of the cardiac end of the stomach, forms a new indication for operation. It is comparable to pyloric obstruction, and the operation for the relief of cardiospasm is similar to that of pyloric stenosis. Mikulicz and others have performed this operation with brilliant results and effected a cure that could be obtained only by surgery.

Pyloric stenosis is another and new indication for operative interference to relieve the distressing symptoms so often disguised under the term of dyspepsia. In 1901 Roswell Park collected upward of 40 cases in which the patients were cured by surgery.

Gastroptosis is a prolapse of the stomach due to relaxation of the ligaments which support the organ. This condition gives rise to ordinary signs of dyspepsia accompained by acute pain and later emaciation. Modern surgery in its evolution has devised an operation for the relief of this distressing and painful condition. The stomach is elevated and held in its anatomic position by shortening of the gastrohepatic and phrenic ligaments of the stomach. Thus the normal ligaments are shortened and the stomach held in its proper position without disturbing its mobility or function. In eight cases reported, including four by Bier, seven patients were cured and one improved. This is a new operation of modern surgery calculated to relieve a distressing condition for which medical treatment was of no avail.

Dilation of the stomach has been operated upon with a view of relief of distressing symptoms to which it gives rise. The operation is called gastroplication and consists in reducing the capacity of the dilated stomach by tucking in folds of the stomach wall. It is a most satisfactory operation, provided there is no pyloric obstruction present. The operation is safe and effects a permanent cure.

Exploration of the stomach has been resorted to successfully by Dennis to relieve hysteric vomiting. Hysteria, as is well known, gives rise to persistent and uncontrollable vomiting, and in one case in which no relief could be obtained by medical means, a laparotomy was performed, the stomach drawn out and then returned into the peritoneal cavity. The psychic effect or the mechanical stretching of the stomach itself resulted in cure.

Gastrotomy for the removal of foreign bodies in the stomach has been resorted to successfully during the past 25 years. The foreign bodies enter the stomach as a result of accident or are purposely swallowed as a livelihood, or on account of insanity. In preantiseptic days, Murphy reports 19 cases of gastrotomy, with 15 recoveries and 4 deaths, or a mortality of 21 %. In antiseptic days, 71 patients were operated upon, with a mortality of 9 %. This includes early and late cases and at the present time if the cases are seen early the mortality is very low. Thus, modern surgery has developed to such a state of perfection that the stomach can be opened and foreign bodies removed with almost a certainty of success.

Gastrostomy is an operation employed for the relief of stricture of the esophagus, either benign or malignant, or for certain lesions connected with the stomach itself. It has for its prime object the prevention of death by starvation.

In 1883 Le Fort compiled some statistics in 105 cases of gastrostomy, in which he showed that the mortality from 100 % was reduced to 74.2 %. In 1885 Zisas collected 162 cases of gastrostomy, with 113, or 69.7 % of mortality. In 1886 Knis had 169 cases of gastrostomy, with a mortality of 66.6 %. In 1887 Heydenreich collected 33 new cases of gastrostomies, with 19 deaths, or 57 % mortality. Since 1887 Guerin has collected 121 cases of gastrostomy, with 43 deaths, or 35.5 % mortality. Mayo has performed gastrostomy with a much smaller death-rate than any mentioned. There can be no more beautiful illustration of the development of surgery than is demonstrated in this one operation, since formerly it was attended by a mortality of 100 %, while to-day, after about a quarter of a century the operation has by evolution achieved a record that is most remarkable, since the latest figures show the mortality to be less than 30 %.

Mikulicz recently performed 10 gastrostomies for the relief of non-malignant strictures of the esophagus, with only 7 deaths, or a mortality of about 20 %.

Dennis operated upon a case of impermeable stricture of the esophagus, caused by ulceration and cicatricial contraction by typhoid ulcers. This case is one of the two in which typhoid ulcers have been found. The patient is now living, seven years after the gastrostomy. His weight previous to the operation was less than 100 pounds, and to-day it is 184 pounds. He had not taken a mouthful of food except through the fistulous opening for several years and is perfectly well nourished.

Gastric ulcer has become a recent indication for operation. It has been performed 184 times as collected by Mayo Robson up to 1900. These 184 cases do not include those for perforation or hemorrhage; 157 patients recovered, and 31 died, thus giving a mortality of 16.4 %. In 1901 statistics show that in 25 % of cases of gastric ulcer the patients died under medical treatment, and only 5 % under surgical treatment, according to the latest statistics. Gastric ulcer is a pathologic condition which formerly was considered exclusively from a medical point of view. To-day this disease in the stage of complication has been relegated to the domain of surgery. It has been during the past quarter of a century that progress has been made in the management of the serious complications, such as hemorrhage and perforation, of this intractable disease. Under medical treatment, the mortality of gastric ulcer in hemorrhage or perforation was nearly 100 %, while under surgical treatment this frightful mortality has been reduced by the Mayos to 5 % in the benign ulcers and 18 % in the malignant ulcers. The advance that surgery has made in this disease has been in the study of the mechanics of the stomach, rather than the chemistry. Medical treatment based on chemistry was of little avail. Gastric ulcer of the stomach affords a striking illustration of the progress of surgery within the past decade. In addition to the reduction of the mortality from nearly 100 % by medical treatment to about 5 % by surgical treatment in the acute cases of hemorrhage and perforation, to 23 % in the chronic cases with malignancy, there has been eliminated the danger of cancer engrafted upon an ulcer which at the beginning was benign.

Gastric hemorrhage is a condition which has been relieved through the mediation of modern surgery. These hemorrhages from the stomach are peculiar in that the smallest ulcers, which can scarcely be recognized by the naked eye on post-mortem appearances, have given rise to fatal hemorrhage. Mayo reports five cases of acute perforation and hemorrhage with three deaths.

Cancer of the stomach was a uniformly fatal disease. Under medical treatment no patient ever recovered. Surgery has entered this domain, and already the beneficent results are beginning to be felt. It must be remembered that this invariably fatal disease reaches, according to Haberlin, 40 % of all the cases of cancer that invade the human body. Here is the most important and serious problem with which surgery has been confronted. Mayo assigns three reasons why surgery has never until recently interested itself in this fatal disease: (1) a belief that cure cannot be accomplished; (2) that the mortality of radical operations is almost prohibitory; (3) that the diagnosis cannot be made until the case is hopeless. In regard to the first reason, Mayo cites the fact that McDonald found 43 cases of cancer of the stomach, in which a permanent cure was effected by operation. Murphy collected 189 cases, in which the operation was performed by several operators, with 5 % permanent cures in cases of over three years' standing. In some of these cures the patients were operated upon more than two years, and hence would, by law of average, survive to bring the percentage up to 8 %. Beside these recoveries, Krönlein has proved by his statistics that human life is prolonged 14 months over the unoperated cases. These facts are in striking contrast to the uniformly 100 % mortality under medical treatment. The second reason why surgery has never generally entered the operative field for the relief of gastric cancer was due to the high mortality of 60 % which Billroth published. This mortality has been happily reduced to 10 % by improvement in technic and by early operation. If the operation is performed before adhesions have formed, and by men thoroughly trained in this field of operative work, the mortality will soon be even less than 10 %. Mayo has had 41 cases of excision of the stomach, with a mortality of 17 %. Out of the total number, 13 were performed by an improved method, with only 1 death, or 6 %, while in the last 11 cases of excision of the stomach there was not a death, or the mortality zero. The mortality has been reduced in Mayo's last series of 11 cases to zero, from 60 %, as reported by Billroth. No other statistics can be adduced to show so emphatically what surgery has achieved within a period of time that has elapsed since the erection of this magnificent building in this wonderful exposition. This one fact alone is the grandest and most striking proof of the miraculous work which surgery has accomplished, and to Mayo is due the credit of leading the world in this new department of surgery, which may be said to be the highest, the final, the most triumphant monument of the contribution of surgery to the human race. Here, again, is another striking illustration of what surgery has achieved. It has reduced the mortality of an operation in cancer of the stomach from 60 % to 10 %, and in a limited number to zero, and with every prospect in the near future of even a mortality of less than 10 % in a large series of cases.

The third reason why surgery has not invaded this field lies in the fact that the diagnosis cannot be made by medical means in time to effect a cure. Exploratory incision to find out is recommended by Mayo, and by this means an early operation can be performed that will be attended by small mortality as regards the operation itself, and a large percentage of cures as regards the disease itself. Cancer of the stomach, as a rule, is situated near the pylorus, just below the lesser curvature. Moynihan states that from this focus it spreads widely through the submucosa, and rapidly toward the cardia, and slowly toward the pylorus. Until very recently no surgery has been done upon the stomach for cancer, for the reason that it was considered a hopeless disease. Murphy collected 189 cases in which radical operation was done, with 26 deaths. Of these, 17 patients survived three years, or about 8 % of cures. This is a gain in the right direction, since all patients die without operation. This 8 % of cures was reduced to 5 % by a return of the disease after three years. Mikulicz in 100 cases had an average duration of life of 15 months. The patients had relief from suffering at least 15 months, and there did not follow that terrible suffering so characteristic of the inoperable cases of cancer of the stomach. The reason that the results are not better in cancer of the stomach is owing to delay in operation, and when that obstacle is overcome the results will be brilliant, compared with the gravity of the disease. Time permits of adhesions, and when the operation is resorted to before adhesions form, the mortality is very much lessened. Thus Haberkaut had a mortality of 72 % in cases with adhesions, and only 27 % without adhesions. Gastrectomy was done, as reported by Murphy, in Kappeler's clinic, with 26 % mortality, Krönlein with 28 % mortality, Kocher 29 %, Roux 33 %, and Mikulicz 37 % mortality. Murphy has called attention to the prophylactic treatment of cancer. He believes in the removal of conditions which seem to be essential in the majority of cases to the development of the disease. Mikulicz has shown that 4 % to 5 % of the human race suffer from gastric ulcer, and that a fifth die as a result of the gastric ulcer. The other factor which largely influences the growth of cancer is the pyloric stenosis when the stomach cannot empty itself. The suggestion, therefore, is the removal of gastric ulcers by excision, and the relief of the pyloric obstruction by gastroenterostomy, and these prophylactic operations when performed early are attended with a comparatively small mortality, eliminates the possibility of cancer of the stomach arising from these two important and frequent causes.

Partial gastrectomy was twice performed by Langenbuch and published by him in 1894. In both cases seven eighths of the stomach was removed. In 1898 Krönlein records all his own cases of partial excision of the stomach and Schlatter's case of complete excision. There were in all 24 cases, with 5 deaths, or a mortality of about 20%. Maydl, in 1899, reports 25 cases of cancer of the stomach, in which a partial gastrectomy was performed, with a mortality of 16%. Of the patients who recovered from the operation, 7 had recurrence very soon afterward, and the average duration of life was 11.7 months. In 1898 Kocher has reported 57 cases of resection of the pylorus, with 5 deaths, or a mortality of 8%. In the list there were 8 patients cured. Rydygier, in 1901, reported 25 partial gastrectomies, in which 8 patients recovered and 17 died, or a mortality of 68%. Czerny, in 1899, reports 29 partial gastrectomies, with 11 deaths, or a mortality of about 40%, and the average duration of life was 22 months. Morison reports 16 cases of partial gastrectomy, with 7 deaths, or a mortality of about 43%. Two of Morison's patients are still living. In one 6 years have elapsed, and in the other about 4 years. Mayo reports 48 cases of partial gastrectomy for pyloric cancer, with a mortality of 12.5%, and in the last 19 cases there was only 1 death.

Complete gastrectomy was first performed by Conner, of Cincinnati, in 1883. The patient died upon the operating table. Complete gastrectomy was performed by Schlatter in 1897. The patient lived 13½ months. Complete gastrectomy was next performed by Brigham in 1898. The patient recovered from the operation. Complete gastrectomy has been performed 12 times, as reported by Robson and Moynihan. Four died as result of the operation, or a mortality of 33%. These cases are too recent for a pronounced opinion as to the permanency of the cure.

Surgery of the liver forms a unique chapter in the development of the science. Operations upon the gall-bladder and biliary ducts afford the most striking illustration of what modern surgery has achieved. Within the past 37 years this new operation has been performed with most gratifying results. It is a source of great national pride that this operation, destined to relieve so much intense suffering and to save life itself, was discovered in this country. To Bobbs of Indianapolis is due the great honor of the discovery of an operation which has accomplished these two beneficent results. In 1867, 37 years ago, Bobbs performed successfully the new operation of cholecystotomy and removed 50 gall-stones by an incision into the gall-bladder. This event marks an epoch in abdominal surgery that places this renowned Western surgeon upon a pedestal that commands homage and respect from the civilized world. Bobbs's first cholecystotomy was soon followed, in 1868, by a second operation by another American surgeon, J. Marion Sims, who removed 60 gall-stones from the gall-bladder. To Tait, however, who was at the time of his death the greatest authority on hepatic surgery, belongs the great credit of perfecting the technic of this operation. Excision of biliary calculi by incision into the umbilical vein was performed by Dr. John C. Warren of Boston within the century. Such in brief is the history of the operation, the development of which from its crude to its almost perfect technic, forms a remarkable chapter in surgery.

Gall-stones with intestinal obstruction are attended under medical treatment, with a mortality of nearly 100 %, while surgery has brought relief in a certain proportion of cases and with every encouraging prospect of a very great improvement. Courvoisier reports 125 cases, with a mortality of 44 %; Schüller had 82 cases, with a mortality of 56 %; Eve 28 cases, with a mortality of 40 %; and Bannard 8 cases, with a mortality of 57 %.

Cholecystotomy is an operation which consists in opening the gall-bladder for the relief of various conditions. Cholecystitis or inflammation of the gall-bladder is a disease that was formerly treated by medical means, with little or no prospect of cure if septic infection was present. In those cases in which gangrene or pus or rupture has occurred, medical treatment is attended by death; but surgical treatment may effect a cure in a large percentage of cases. Cholecystotomy is one of the most gratifying operations in surgery, because it relieves suffering, effects a permanent cure, and is attended by the exceedingly low mortality of less than 3 %. The statistics of the operation of cholecystotomy varies greatly, owing to the special conditions for which the operation is performed. Mayo Robson states that when the operation is performed for simple disease, as gall-stones, when malignant disease and jaundice with infective cholangitis are absent, the mortality in 281 cases was only 1.06 %. If now the complicated cases are included, such as phlegmonous cholecystitis, gangrene of gall-bladder, infective cholangitis with or without gall-stones, the mortaliy is only 2.7 %. If further the malignant cases be collected, in which cholecystotomy has been resorted to in the presence of cancer of the pancreas or bile-ducts, the mortality of the operation itself in 22 cases was only 5.8 %. As regards the recurrences, the statistics will be mentioned latter. Mayo reports, in 1902, 227 cases of cholecystotomy for various simple conditions, chiefly for gall-stones, with 6 deaths, or a mortality of 2.6 %. The same operator reported, in 1903, 352 cholecystotomies for simple conditions, with 8 deaths, or a mortality of 2.27 %. For malignant disease the same surgeon reported, in 1902, 4 cholecystotomies, with 2 deaths, or 50 % mortality, and in 1903, 5 additional cases, with 3 deaths, or 60 % mortality. It is thus evident that cholecystotomy is attended by a high mortality when the operation is performed for cancer. It must be remembered, however, that the mortality is 100 % under medical treatment. The mortality of 100 % under medical treatment will never be improved, while the 50 % or 60 % mortality under surgical treatment will be reduced as diagnosis and technic improve, and early operation is performed. Kehr, in 1896, reported 209 cholecystotomies upon 174 patients. In the simple cholecystotomies, the mortality was only 1 %. In the complicated cases the mortality was 58.8 %. In a later series Kehr reported 202 cholecystotomies with 32 deaths, or a mortality of 16 %. The higher mortality in this series is accounted for by the greater severity of the cases which earlier did not submit to operation. In conservative cholocystotomies Kehr had 68 operations with three deaths, or a mortality of 4.4 %. In 1902 Kehr again reported his statistics, which consisted of 720 operations for gall-stones, with a mortality of 15 %. In the simple cases of cholecystotomy the mortality was 2.1 %, and in the complicated cases, including cancer, the mortality was 97 %. Greig Smith reported 11 simple cholecystotomies with no mortality, and one complicated case with death, or 12 cases in total, with a mortality of 8.33 %. Lawson Tait reported 55 cases of cholecystotomy with three deaths, or a mortality of 5.4 %.

Thus in cholecystotomy alone is an operation that has shown a steady improvement in its statistics. In no other operation is a greater contrast between the medical and surgical treatment of a disease at the present day.

Cholecystectomy is an operation which consists in excising the gall-bladder in a manner somewhat similar to the removal of the appendix. Ferrier reported, in 1901, 16 cases with 4 deaths, or a mortality of 25 %. Courvoisier reported 47 cases with 12 deaths, or a mortality of 25 %. Martig, in 1894, collected 87 cases of removal of the gall-stones with 15 deaths, or a mortality of 17.2 %. Mayo Robson reports 28 cases with 4 deaths, or a mortality of 14.2 %. Mayo, in 1902, had 31 cases with 3 deaths, or a mortality of 9.6 %, and in 1903 had 70 cases with 3 deaths, or a mortality of 4.3 %, and up to the present time he states that he has had 204 cases with a mortality of 4 %. Kehr reported 21 cases with 1 death, and a mortality of 5 %, and later another list with the mortality of 3 %. Thus in cholecystectomy is another operation that has shown steady improvement in its statistics. This operation affords another illustration of the marked contrast between the medical and the surgical treatment, for in the former treatment no cure can be effected, while in the latter the percentage is very large.

Choledochotomy is an operation which consists of opening one of the biliary ducts and is a more formidable operation than opening the gall-bladder. Ferrier, in 1893, reported 20 cases, with a mortality of 25 %. Kehr, in 1896, reported 84 cases, with 31 deaths, or a mortality of 37.8 %. In a later series his mortality was reduced to 12.5 %. Mayo states that in 130 cases of benign series he had a mortality of 7.75 %. Mayo Robson reported, in 1901, 37 cases, with 4 deaths, or a mortality of 10 %, and since 1901 51 cases, with 1 death, or 1.9 %, and later a consecutive series of 52 choledochotomies with no deaths. Choledochotomy is one of the most difficult operations in surgery, and the advance which surgery has made is shown by a reference to the great mortality of these cases for which this operation is performed, since under medical treatment suffering was not relieved and death often supervened, whereas under surgical treatment the mortality has been reduced even to 1.9 %.

Cholecystenterotomy is a modern operation on the biliary passages, and consists in establishing a new communication between the gall-bladder and the intestine. Murphy reported 23 cases by use of sutures, with 8 deaths, or a mortality of 34 %; 21 cases by Murphy's button, with no mortality, and 2 cases for malignant disease, with 2 deaths, or a mortality of 100 %.

Cholecystduodenotomy has been performed by Murphy's button in 67 non-malignant cases with only 3 deaths, or a mortality of about 4 %, and in 12 malignant cases by Murphy, 10 died, or a mortality of 83.3 %. Mayo performed cholecystduodenotomy on 5 patients for chronic pancreatitis with no death, and 4 times for cancer with 1 death, or a mortality of 25 %.

Pancreatic disease affords a field for the display of what modern surgery has achieved that astonishes the scientific world. Körte has computed the mortality of the operation for the cure of pancreatic cysts, and shows that Gussenbaur was the first to operate for the relief of this fatal disease. Previous to Gussenbaur's operation, the mortality under medical treatment was 100 %. In the 84 cases collected by Körte, five patients died as the immediate result of the operation, thus giving the low mortality of not quite 0.6 %. This statement seems incredible and affords the most startlingly unprecedented illustration which has no parallel in any other science. This operation has attracted great attention in the scientific world and its brilliant and unique record has been heralded throughout Christendom. Still more striking is another report of 15 cases of complete excision of the cyst of the pancreas with 13 recoveries, or a mortality of about 13 %, and in 7 additional cases the extirpation has been only partial, since some of the cyst-wall was so adherent to important structures that its removal was impossible and 4 of the patients died, thus giving a mortality of 57 %, which in contrast to 100 % mortality under medical treatment is a great advance, though it is admitted that it is not what is expected, since as technic improves, the operation will be brought perhaps nearly as low as simple ovariotomy in the future. In evacuation and drainage of the pancreatic cyst there have been collected by Takaysan 17 cases with 1 death, a mortality of not quite 6 %. Mayo had 5 consecutive cases of chronic pancreatitis with recovery in each case, and 4 cases of cancer of the pancreas with 1 death, or a mortality of 25 %. Operations upon the pancreas afford another brilliant example of the achievements of surgery within the past few years. Mayo Robson and Moynihan, in 1902, reported 24 operations for the relief of chronic pancreatitis with 2 deaths and complete and perfect recovery in the 22 remaining cases. There is no more striking example of the progress which surgery has made than is afforded by this record. In cancer of the pancreas, which is always fatal, the operation has been attended by about 50 % mortality, and in the other 50 % the patients have survived a comparatively short period. This is an operation in which surgery in the future will have a better showing just as soon as the methods of diagnosis are improved so as to operate in the early stages of the disease. Mayo has had 37 cases of pancreatic disease with 2 deaths, or a mortality of about 5 %.

Surgery of the spleen offers an illustration of the progress which surgery has made during the past century. The cases of major operations upon the spleen are too few to make any extensive and reliable statistics. The prognosis which is most marked, and which interests us in connection with the subject of this address, shows improvement each year. Thus Murphy shows that in 1890, in the operated cases, the mortality was 70 %. In 1897 the mortality was 37 %. In 1899 the mortality was 26 %. These figures are unsatisfactory, except to point out that in this new department of surgery great advance is made each year. Fevrier grouped under four heads the surgical conditions in the spleen that call for operative interference. They are traumatism, abscess, tumors, and displacements. As these conditions were nearly all fatal without surgical intervention, it is interesting to inquire what surgery has accomplished in this new field. Fevrier collected 56 cases of rupture of the spleen, in which splenectomy was performed 46 times, with 23 recoveries, thus giving a mortality of 50 %. There were 8 cases of stab and gunshot wounds, with 3 deaths, or a mortality of 30 %. Abscesses and hydatid cysts have called for operative interference, but there are no reliable statistics on the results. Malarial splenomegaly was operated upon 117 times, with 31 deaths, or a mortality of 26 %. Displacements of the spleen have been operated upon by spenectomy and by splenopexy. Cases of extirpation of a movable spleen have been collected by Stierlin, who shows that the mortality is now only 6.25 %. Splenectomy in echinococcus of the spleen, according to Bessel-Hagen, previous to 1890, was attended with a mortality of 60 %, and from 1891 to 1900 the mortality was reduced to 10 %.

Tuberculous peritonitis has been taken out of the realm of internal medicine and transferred to clinical surgery. It has now become an established routine of practice that laparotomy is justifiable in cases of ascites in which the etiology does not depend upon disease of the liver, kidney, or heart. The method of invasion of the bacilli in their attack upon the peritoneum varies in different cases. The bacilli in rare instances may gain entrance through a perforation from a tuberculous intestinal ulcer, or from a purulent tuberculous vaginitis. Again, the peritoneum may become infected through a perforating tuberculous appendicitis, or from a tuberculous ovary, or fallopian tube. Williams, of the Johns Hopkins University, has shown that from 40 % to 50 % of the cases of tuberculous peritonitis can be traced to this origin. Abbe has demonstrated that about 66 % of the cases of tuberculous peritonitis are due to infection of the thoracic lymph-nodes, and in only 16 % is entrance gained by the mesenteric glands. It is thus evident that, while 16 % of the cases of tuberculous peritonitis can be explained by infection through the alimentary canal from milk or other kinds of infected food, the great proportion is due to infection from the thoracic lymph-nodes. There is little doubt but tuberculous peritonitis may arise as a secondary affection following tuberculosis of the intestinal canal. Here again inhibition of infected milk and meats play an important rôle. The entrance of tuberculous sputum into the stomach in those affected with pulmonary tuberculosis explains intestinal and peritoneal infection. The latter method of invasion is considered a frequent cause of peritoneal tuberculosis. The presence of tuberculous ulcers in the stomach in phthisical patients who subsequently suffered from intestinal tuberculosis has been thus explained by the investigation of Klebs. Many experiments upon lower animals which were fed by food containing tuberculous sputum and fragments of tuberculous lung have proved beyond doubt that intestinal and peritoneal tuberculosis can arise in this way. It is a strange clinical fact that laparotomy for the cure of this disease has become established as a recognized procedure through errors of diagnosis. Sir Spencer Wells cured a case of tuberculous peritonitis by a laparotomy performed under the supposition that it was ovarian disease. Laparotomy, however, as a curative measure, was first introduced by Dr. Van de Warker, of Syracuse, N. Y. He blundered upon a case of tuberculosis of the peritoneum, under the supposition that he was operating for the cure of a case of hydrops of the peritoneum. Dr.

Van de Warker presented this case at a meeting of the New York State Medical Association in 1883. From this time on, the operation of laparotomy for the cure of tuberculosis of the peritoneum has been practiced. The operation has, however, been modified from year to year; but most surgeons still adhere to the simple operation at first devised by our American surgeon. As regards the result of laparotomy for the cure of tuberculous peritonitis, surgeons differ largely in their statistics. Parker Syms shows that some claim 80 % of cures, while others 24 %. Marked improvement follows in 80 % of the cases, and the mortality of the operation is only about 3 %. Syms concludes that it is safe to estimate that 30 % of the cases of tuberculous peritonitis are permanently cured by laparotomy.

In suppurative peritonitis surgery has opened up a new field within the past few years. The operation of incision into the peritoneal cavity has effected cures in a class of cases that heretofore were uniformly fatal. Murphy reports 7 recoveries out of 9 cases, or 77 % of recoveries in diffuse suppurative peritonitis following appendicitis, while Dennis has had 11 cases of diffuse suppurative peritonitis without a death.

The radical cure of hernia presents one of the most forcible illustrations of the onward march of surgery. Coley reports 1003 operations with a mortality of less than a fifth of 1 %, and with relapses of less than a tenth of 1 %. When it is considered that nearly one person in every 20, and even by some statisticians one to every eight, persons is born with a rupture, and these patients must wear trusses, the bane of human existence, and which are as necessary to the comfort and safety of the patient as a splint is to a fractured leg, the untold blessings of this one contribution of surgery to the human race become strikingly apparent. In other words, surgery offers to the thousands affected in this way a sure, perfect, and safe cure, and with the complete elimination of the uncomfortable, inconvenient, often painful, and sometimes dangerous instrument of barbaric times, the truss. What aseptic surgery has accomplished for the human family in the relief of this one distressing and common condition, no one can appreciate except he who has been the recipient of this blessing offered to him by the science of surgery. Until recently great expense was incurred and time consumed in fitting trusses. Many of these patients died as a result of strangulated hernia, which formerly had a mortality of over 50 %. Now the possibility of strangulated hernia is eliminated and a radical cure effected with less than 1 % mortality and 1 % relapse. Perhaps one of the most forcible arguments to show the effect of certain improvements in the technic of surgical operations is demonstrated by the use of rubber gloves. In 116 cases of hernia operated upon at the Johns Hopkins Hospital prior to 1896, there were 28 cases of suppuration in the wounds, or 24 %, while in 226 cases of the same operation with rubber gloves upon the surgeons' hands there were 4 cases of suppuration, or a fraction over 1 %.

In umbilical hernia Mayo has devised an operation that offers relief to those patients who heretofore followed a life of constant suffering and danger. Mayo first performed his overlapping operation in 1895, and in a series of 50 cases there was no mortality and no relapses except in which the relapse was only a partial stretching.

The operation for the relief of acute appendicitis is clearly traced to the work of American surgeons. In 1843, Willard Parker, and later Gurdon Buck, did much to explain the nature of these iliac inflammations, and Sands cleared the way for the perfected operation of McBurney, which aims to prevent these dangerous peritoneal inflammations, and to prepare the wound for aseptic healing. Sands also first operated with success after perforation had taken place and general peritonitis was present. To McBurney is due great credit for the perfection of this operation, which is now recognized throughout the world as the best, safest, and most scientific way of managing these varieties of suppuration hitherto so fatal. The operation of removing the appendix vermiformis during the quiescent period between relapsing attacks was suggested by Sir Frederick Treves, of London, although the appendix was successfully removed in this country by Dennis in 1887. In this case the appendix was diseased, owing to adhesions to an ovarian tumor.

The surgery of the appendix is most interesting with a view to a study of what surgery of the past century has accomplished. There is probably no surgical disease about which so much has been written as appendicitis. The subject is trite and threadbare in many respects. There is little to be learned in regard to the etiology, symptomatology, and diagnosis of the disease. The operative technic can be but little improved upon in its present state of perfection. The mortality under proper antiseptic and aseptic conditions is so low that in the nature of the disease it will never in all probability be brought much lower. The percentage in these days of aseptic surgery in this abdominal operation is less than the percentage in the simple amputation of the finger in the preantiseptic days. It would seem that surgery had reached its climax in regard to mortality in operation for the relief of appendicitis, yet the time will never come when there will be no death-rate. Complications are certain to arise that are beyond the control of the surgeon. Crural thrombosis, intestinal obstruction, acetonemia, embolism, shock of operation, intercurrent affections, all afford examples to show that some mortality must always exist. If a fraction of a per cent can be gained in the reduction of the mortality, it is an advance in the right direction. The experience of surgeons during the past few years has demonstrated new methods, has pointed out new ways, and has discovered new facts, all of which tend to reduce the mortality. It seems now the only thing that is left is to combine the various views of experienced surgeons into some uniform plan of treatment, in order to produce the best results. The mortality in appendicitis in all cases under medical treatment is about 16 %, with 30 % of relapses, while in diffuse suppurative peritonitis it is almost uniformly fatal.

The mortality in appendicitis in all cases under surgical treatment is about 4 %, and with no relapses, and in diffuse suppurative peritonitis the mortality in published statistics is from 31 %, the lowest, to 91 %, the highest, and in my 11 consecutive cases of diffuse suppurative peritonitis the mortality was zero.

Ochsner has recently contributed some statistics from his own operations during one year, which reflect great credit upon his excellent work. In the acute there was a mortality of 3 %, and in the chronic cases there was a mortality of 1 %. In the entire number of cases, both acute and chronic, there was a mortality following the operation of 2 %. Deaver has also recently contributed some statistics from his own operations extending over a period of one year, which likewise reflect great credit upon his surgical skill. In the cases of general diffuse peritonitis there was a mortality of 31 %. In the cases in which there was abscess there was a mortality of 12 %. In the cases in which the disease was confined to the appendix, with stricture, ulceration, and necrosis of the mucous membrane, there was a mortality of 0.8 %, and finally, in all the cases operated upon, the total mortality was 5 %. Richardson's published statistics are practically the same, and the result of these various operators gives an idea of what surgery has accomplished. In a study of the last 119 cases of appendicitis occurring in my practice up to April 1, 1903, the mortality of the disease, irrespective of operation or of any special plan of treatment, was a little over 1.5 %. In the cases treated without operation in which the attack was a mild, catarrhal one, and in which the patients were not operated upon during the attack, the mortality was zero. In this group of cases in which conservatism was employed for special reasons, the appendix was in many cases subsequently removed owing to repeated attacks, and the mortality was zero. In the group of cases in which the appendix was gangrenous and had ruptured into the peritoneal cavity with a general peritonitis, of which there were 11 cases, the mortality was zero. In the cases in which there was an acute perforative appendicitis, and in which the appendix was gangrenous, and found in a circumscribed abscess cavity, the mortality was 7 %. If now, in this group, all the operative cases are collected, both acute and chronic, the death-rate was 2 %. If the two fatal cases in the entire list of 119 cases are eliminated, which were hopeless from the start, but which were operated upon because it was offering the only possible chance of life, forlorn as the prospect was, the mortality of the disease was zero. The mortality of the operation both for acute and chronic appendicitis was also zero. Such cases as the two in which death occurred will always happen, and will always prevent the absence of mortality in the disease. In other words, if the two fatal cases are eliminated on the ground that surgery is powerless to save when complications such as empyema and abscess of the lung exist, the mortality in the medical and operative treatment of this disease in 117 consecutive cases was zero. The two deaths which make the mortality of the operation in all cases about 2%, which in itself is insignificant when the nature of the disease is considered, deserve special consideration.

Richardson, of Boston, reports 574 appendectomies in the interval, with no deaths. Mayo has had 1668 cases in the interval, with two deaths, one from pneumonia secondary to an intercurrent attack of grip, and the other to surgical kidney following the use of catheter in an enlarged prostate.

Acute intestinal obstruction is a condition in former years almost universally fatal, while to-day surgery has afforded relief in this disease. Thus Wiggins gives a mortality of 67.2% for laparotomy. Excluding cases in which either the operation was abandoned, the bowel incised, and an artificial opening made, resection attempted, or an anastomosis effected, there are 45 cases, in which 24 resulted fatally, or a mortality of 53.4%. Counting only the operations that have been performed since 1889, and throwing out those cases in which the operation was not completed, we have a total of 18 cases, of which 14 were successful, and 4 unsuccessful, giving a mortality of only 32.2%. This Wiggin believes to be a fair estimate of the risk to-day of laparotomy performed in a young infant for the relief of this condition, if performed within the first 48 hours of the onset. This gives a chance of success represented by 78%, which, according to this author, would speedily rise to 90%, as the patients come more frequently to operation during the first 24 hours.

Cancer of the bowel is a uniformly fatal disease. The recent advances in surgery have been the means of saving some of these patients. Mikulicz and Körte have each reported 12 cases of operations in which 9 of these cases had no return after four years, which is equal to 37% of permanent cures. Dennis operated upon a patient with cancer of the cecum, resecting six or seven inches of the bowel, and subsequently making an anastomosis with Murphy's button. The patient is now perfectly well after a lapse of many years since the operation.

Laparotomy was performed by Dr. Wilson, in 1831, for the relief of intussusception. The patient was a negro slave, and had suffered from intestinal obstruction for 17 days. The abdomen was opened, the intussusception was found, and it was drawn out and released, and the patient made a complete recovery.

In 1809 Physick was the first to ligate the éperon, when an artificial opening had been made in the intestine on account of pathologic changes. In 1847 Gross urged the excision of a section of the intestine, with suturing of the divided ends, with a view to establish the continuity of the canal, but the patient refused, and in 1863 Kinloch, of South Carolina, accomplished this result. In 1834 Luzenberg laid open a strangulated hernia, found it gangrenous, excised the mortified section of the intestine, stitched the serous surfaces, and the patient fully recovered. This same surgeon suggested, in 1832, exclusion of light to prevent pitting of small-pox. The operation of laparotomy for the treatment of penetrating gunshot and stab wounds of the peritoneal cavity was the work of American surgery. Gross, in 1843, and Sims, just before his death, both suggested this method, but these surgeons never practiced this method of treatment. It remained for Bull, of New York, to make the practical application of the method, and to him is due the credit of this great advance in surgery. It is a source of national pride that laparotomy in penetrating wounds, and visceral injuries of the abdomen, was conceived, developed, and perfected in America. The widespreading influence of this operation is felt in abdominal surgery, and much of the present advance is the result of Bull's surgery.

Cancer of the rectum is a disease which was formerly uniformly fatal. Modern surgery has, however, rescued many of these unfortunate victims from a most distressing and painful death due to inanition, hemorrhage, and exhaustion. Taking the three-year limit as a point when it can be fairly stated that a return is rare after an operation, Krönlein collected 640 cases with a cure of 14% of over three years' lapse of time from the operation. Czerny, Bergmann, Kraske, and other surgeons report from 20% to 30% of permanent cures, and Kocher has had as high as 50% of permanent cures. The statistics of Kocher will be even improved upon as technic is perfected and early operation performed.

The first and only successful case of *laparotomy for the relief of perforation of the intestine* during the progress of typhoid fever was performed in this country, and to Dr. Weller Van Hook of Chicago is due the credit of having first established an operation for the relief of these cases, which hitherto were fatal.

Perforation in typhoid fever has given rise to an operation for the relief of fatal suppurative peritonitis. This operation is one of the most signal triumphs in modern surgery. In 1884 Leyden suggested and Mikulicz performed the operation. Haggard collected 295 cases in which operation was done up to May 1, 1903. Haggard states that 500,000 cases of typhoid fever occur in this country alone every year with a mortality of about 10% to 15%. Thus 50,000 to 75,000 patients perish annually from this disease. Osler states that a third of the deaths in typhoid occur as a result of perforation and "Taylor thus estimates that 25,000 deaths occur yearly from this accident. On a basis of a possible 30% recovery by operative interference he further concludes that 7500 persons perish in the United States each year who might be saved." The mortality of perforation in typhoid is estimated by Murchison at 90% to 95%, and Osler says that "he could not recall a single patient in his experience that had recovered after perforation had occurred." Harte has shown that the mortality has steadily decreased as earlier operations were performed and technic improved; thus in 277 cases in successive intervals the mortality was as follows:

1884 to 1889, 10 cases; mortality ....90.0 %
1890 to 1893, 16 " " ....87.5 %
1894 to 1898, 110 " " ....74.5 %
1899 to 1902, 141 " " ....66.6 %

Duodenal ulcer has been operated upon with great success and is a signal illustration of what modern surgery has accomplished. Mayo operated upon 56 patients, in which 6 of the operations were for the relief of acute condition, with 3 deaths, or a mortality of 50%; and 50 operations for the relief of chronic condition, with 1 death, or a mortality of 2%. This operation marks an important epoch in the history of surgery. When the nature of the lesion is considered, the record is a most brilliant one. The difficulties of the diagnosis can only be appreciated when it is considered how similar are the symptoms of duodenal ulcer with pyloric ulcer, gastric ulcer, gall-stones, and other neighboring lesions. A few years ago there was no surgeon who was bold enough to attempt this life-saving operation. The uncertainty of the diagnosis and the frightful mortality that would have ensued made this operation for the relief of duodenal ulcer impossible.

Penetrating wounds of the abdomen are treated at the present time by an exploratory laparotomy, the value of which operation is evident by statistics reported by Postemski in 1891, in which he demonstrated that 60% to 70% of 645 cases of penetrating wounds of the abdomen terminated fatally, while the mortality was 100% when the abdominal viscera were injured. In a later series of penetrating abdominal wounds there were 36 uncomplicated cases, in which the patients were treated by exploratory laparotomies; all recovered, and 22 cases of penetrating wounds of the abdomen associated with intra-abdominal injury, in which 12 patients recovered.

Rupture of the intestine affords another striking illustration of the progress of surgery. Siegel has collected 532 cases in patients treated without operation and the mortality was 55.2%. In 376 cases in which operation was done, the mortality was 51 %. This does not seem so great a triumph for surgery as might be expected, yet if these statistics are carefully gone over it becomes evident that the mortality is due to a cause which in the future can be obviated. Aggressive surgery can do much in these serious cases if operation is not postponed too late, as shown by Senn, and as for example:

Cases operated first 4 hours, mortality	15.2 %
" " 5 to 8 hours, mortality	44.4 %
" " 9 to 12 " "	63.6 %
" " later	70.7 %

Rupture of the stomach has been cured by laparotomy; thus Petry found 44.5 % of recoveries in 18 patients operated upon within 24 hours after the injury, and 25 % of recoveries in 24 patients operated upon more than 24 hours after rupture.

Gangrene of the intestine forms an indication for resection of a segment of the intestine and offers a prospect of recovery in a class of cases otherwise fatal. Thus Roswell Park resected 8 ft. 9 in. of bowel for the relief of a gangrenous condition and the patient recovered. The same surgeon assembled from surgical literature 16 additional cases in which over 200 cm. of bowel were resected with 14 recoveries, or 80 % of cures, or a mortality of 17 %. A singular fact recorded by Park is that when from 100 cm. to 200 cm. was removed, the mortality was 30 %.

Subphrenic abscess is another serious condition which terminates, as a rule, fatally; but in which surgical intervention has been followed in a certain percentage of cases, thus Maydl records 74 operations with 39 recoveries, and 35 deaths, or a mortality of 47.2 %.

Ovariotomy forms a new milestone in the march of surgery. In all probability the most important surgical event that has ever happened in this country and the world, was the conception, birth, and development of ovariotomy. To Dr. Ephraim McDowell of Danville, Ky., belongs this great honor. In 1809 he was the first one to perform this unique and original operation which has made his name immortal. The far-reaching influences that have proceeded from this step are incalculable. Dr. McDowell is to-day recognized as the originator of not only one of the greatest operations in surgery, but also as the author of an operation, the influence of which has made it possible to develop the present wide field of abdominal surgery. McDowell's work will live in the memory of thousands in this land, and will be honored the world over as long as time endures. In 1821 Dr. Nathan Smith performed ovariotomy in Connecticut, and without the knowledge that it had been performed by McDowell; Smith dropped the pedicle into the abdominal cavity and thus made a great advance in McDowell's operation. In 1823 Allan G. Smith also performed an ovariotomy in Kentucky, and David L. Rodgers in New York in 1829. All these cases of ovariotomy were successful.

It was seven years after this last American operation before ovariotomy was first performed in England, and nearly 15 years before ovariotomy was first performed in France. In 1870 T. Gaillard Thomas first devised and performed successfully a vaginal ovariotomy. In 1872 Dr. Davis, of Pennsylvania, performed successfully the same operation, followed in 1873 by Gilmore of Alabama, and in 1874 by Battey of Georgia, and later by Sims. In 1872 Battey performed his first oophorectomy, "with a view to establish at once the change of life for the effectual remedy of certain otherwise incurable maladies." This is an operation also of purely American origin, and has contributed much to the relief of human suffering. It has been urged that while to an American surgeon the credit is honestly due for the first performance of an ovariotomy, other nations have perfected the operation, and more credit is due to-day to other nations for the best results. Let us see how this statement accords with facts. In 1857 the question of ovariotomy was brought up for discussion at the French Academy of Medicine, and only one surgeon considered the operation as sometimes justifiable. Up to that time there had been in America 97 ovariotomies, with 34% mortality; in Great Britain, 123 operations, with 43% mortality; and in Germany, 47 operations, with 77% mortality. American surgeons, therefore, not only obtained the best results up to that date, but no American surgeon to-day will concede that our results are inferior to those obtained by surgeons in any other country at the present time. Few men can realize the influence of McDowell's first ovariotomy upon the whole field of abdominal surgery. It is, indeed, a sublime thought to consider that a man was found with the courage of his convictions to do what no man had ever done, and to operate with the noise of an infuriated mob beneath his windows. This mob would have lynched him if the patient upon whom this first ovariotomy was performed had died. Having escaped the angry mob, he was pointed out as a murderer by his fellow colleagues, and was condemned by the highest scientific authorities in Europe. In America, therefore, under such circumstances and under such conditions, the birth of the greatest operation in surgery occurred — an operation which saves now the lives of millions of women. Keen asserts that "it is estimated that one million years are added every three years to the life of women in this country alone by a single operation of ovariotomy."

The disapproval of this great operation of McDowell's by the press, by the profession, and by the laity was pronounced. The *Medico-Chirurgical Review*, speaking of McDowell's achievement, says: "A back settlement of America, Kentucky, has beaten the Mother Country, nay, Europe itself, with all the boasted surgeons thereof, n the fearful and formidable operation of gastrotomy with extraction of diseased ovaries." All this vituperation was hurled at McDowell; but time, as the great arbiter, has demonstrated that what was said in sarcasm has become a transcendent and mighty truth. The noble character and the true grandeur of McDowell's nature, and his high and lofty ambitions, are illustrated by the fact that he had performed three successful ovariotomies, operations never before undertaken by man, without heralding the victories as triumphs of his personal ambition. In the early days of ovariotomy, McDowell, and Nathan Smith, the Atlees, Dunlap, Peaslee, Kimball, Sims, and Thomas established and brought to the front an operation against which the most bitter and scathing invectives were aimed. These great men, who have placed this operation upon a firm basis, deserve the gratitude of a nation, and of the world, since they have thrown a flood of light upon this dark region of surgery, which is now illuminated by the work of recent operators whose successes are simply miraculous.

Mayo Robson has contributed an article on the evolution of abdominal surgery, a part of which has reference to the results obtained in ovariotomy. He states that in Leeds Infirmary, in 1870–1871, no case was reported under abdominal surgery. In 1901, or 20 years later, there were performed in the Leeds Infirmary 569 abdominal sections. In reference to ovariotomy, he states that about 1870 ovarian tumors were considered a variety of dropsy, and tapping was resorted to as a means of transient alleviation. Thus, in 1870, in St. Bartholomew's Hospital, London, there were only 3 ovariotomies performed, with 100% mortality. In Guy's Hospital, London, 5 ovariotomies, with 60% mortality. In St. Thomas' Hospital, London, 1 ovariotomy, with 100% mortality. In St. George's Hospital, London, 2 ovariotomies, with 100% mortality. In 1875, ovariotomy had such unfavorable statistics that tapping was done to defer a radical operation. In 1875, in 12 cases of ovarian tumor, only 7 patients had an ovariotomy performed, and 5 died, thus giving a mortality of 71%.

Now mark the contrast. In 1901, ovariotomy was performed 64 times, with 4 deaths, or a mortality of about 6%. When it is considered that in these cases some were malignant, gangrenous, and suppurating cases, the story seems incredible. Mouillin reports, in 1901, 57 ovariotomies in the hospital for women, with no death. Richardson, of Boston, reports 93 consecutive ovariotomies without a death. Ovariotomy in the aged shows most remarkable results; thus Kelly has reported in his book over 100 ovariotomies in women who were over 70, and operated upon by 59 surgeons, with only 12 deaths. This is a triumph of surgery that Ephraim McDowell foreshadowed in his courageous work. Sutton collected, in 1896, 11 cases of ovariotomy in women over 80, with no deaths.

Ovariotomy during pregnancy has likewise a most astonishing record, since Williams in his book reports 142 cases collected by Orgler, with only a mortality of 2.77 %.

In 1902, in one London hospital there were 40 ovariotomies, with 1 death, or 2.5 % mortality, as contrasted with 100 % mortality about 1870. Thus in a quarter of a century the mortality has been reduced in one of the most formidable operations in surgery from 71 % to 6 %, and in exceptional series of cases even to 2.5 % mortality. It may be of interest to show the progress which surgery has made during the century in reference to the operation of ovariotomy, from 1809 to 1904.

In America —	McDowell	1809, and later,	12 cases;	mortality,	66 %
	N. Smith.........	1821,	1 “	“	0 %
	A. G. Smith	1823,	1 “	“	0 %
	Several operators	1855,	21 “	“	70 %
	In America	1857,	97 “	“	34 %
	In England......	1857,	123 “	“	43 %
	In Germany	1857,	47 “	“	77 %
	Hofmeier	1903,	200 “	“	4.5 %
	Hofmeier	1903, last,	115 “	“	1.74 %

From the above table it appears that during the first quarter of the nineteenth century, according to the combined reports of McDowell and N. and A. G. Smith, the mortality in 14 cases of ovariotomy was 57 %. The combined English and American returns for 1855 and 1857 give an average mortality of 48 %. The most recent figures are by Hofmeier, for 1903, who returns a mortality of 1.74 %. If the earlier mortality prevailed at the present time, Hofmeier would have had 180 deaths in a total of 315 cases, instead of 11, which actually occurred.

Hysterectomy, or removal of the entire uterus, with or without the ovaries and tubes, affords a most striking illustration of the recent development of surgery. Hysterectomy shows brilliant results when performed for malignant disease; but the result of the operation when performed for malignant disease is the darkest chapter in the present status of surgery. Bigelow collected, in 1884, 359 cases of hysterectomy for fibroids of the uterus, with a mortality of 58 %. Kelly reports, in 1898, 100 cases of hysterectomy, including extirpation of the ovaries and tubes, with a mortality of only 4 %. Pryor has investigated the subject of the mortality of abdominal hysterectomy for myofibroma of the uterus, and states that it is not over 2 %, while in fibrocysts of the uterus, it is much higher, reaching at least 10 %, and states that this great increase in mortality is due to "coexisting cardiac lesions, which so often accompany fibrocystic disease." Pryor also states that his mortality of hysterectomy in pus cases is about 3 %. Noble reports 58 cases of pyosalpinx and abscess of the ovary, in which he performs hysterectomy with removal of the appendages, and the immediate mortality was not quite 2 %, and 36 cases of removal of the appendages without hysterectomy, with a mortality of 5 %. Richardson, of Boston, had a mortality of 3 % in 111 cases during the past two years; and Polk, of New York, has had a long series of cases with equally brilliant results. Webster reports 65 hysterectomies for infective disease of the uterus and appendages, with a mortality of 1.07 %. With such an array of statistics before us in hysterectomy, which may be considered the keystone of the arch, there is no more forcible illustration of the steady advance of surgery than the improvement in this operation. In regard to vaginal hysterectomy, statistics are likewise brilliant; thus Pryor has collected 228 cases of vaginal hysterectomy for non-malignant disease, with one death. Webster reports 40 cases of vaginal hysterectomy for malignant disease of the uterus, with no death from the operation itself. No mention is made of the percentage of permanent cures in these cases.

Hysterectomy for the cure of cancer furnishes the most discouraging and melancholy statistics of any modern operation. In this case it is not so much the fault of the technic as it is the disease which calls for the operation. Cancer is most fatal in the uterus; but the time will soon come when early operations will effect a far greater percentage of recovery. Cancer of the cervix and body of the uterus is most fatal, yet the faintest glimmer of dawn is upon the horizon, and the results of hysterectomy for the permanent cure of cancer are beginning to show signs of improvement. In the history of every great operation the mortality is high at first; but as technic improves and early and radical operations are resorted to, the result will be different. Ovariotomy passed through just such a crisis, and it is certain that hysterectomy for cancer will show better results in the future and if so it will be the greatest triumph of surgery. The statistics of hysterectomy for cancer are subject to the widest variation. Penrose states that his results have been most discouraging, as he has only two or three patients who have permanently recovered. Penrose also criticises the report of 20 % of cures for cancer of the uterus at the Johns Hopkins Hospital, and claims that "after due deduction and thorough sifting of their figures, 5 % of cures comes nearer the actual truth." The mortality of the operation itself for the cure of cancer has a favorable showing in contrast to the results of permanent cure. Thus Pryor, in 1901, reports 98 cases of hysterectomy for cancer of the uterus with a primary mortality of about 11 %. In a very careful and thorough research of the literature of the subject, I find that abdominal hysterectomy for cancer has an immediate mortality of nearly 20 %, if the cases from all available operators are taken, and that the immediate mortality for vaginal hysterectomy for cancer has been as high as 16 %, and by some operators reduced to almost zero.

The Surgery of the Bones and Joints. The management of fractures has brought out the wonderful mechanical ingenuity which is a characteristic of the human mind. The application of the plaster-of-paris bandage in the treatment of fractures is one of the greatest improvements of the century. To the perfection of its technic, Fluhrer's work deserves special commendation. The use of flexible narrow strips of tin or zinc in the management of fractures was devised by Fluhrer in 1872, with the object of securing immobility of the fractured bones. The strips are not designed to act as rigid supports, although incidentally, by their width (a quarter of an inch) they edgewise oppose resistance to angular motion when passing through or near an axis of motion. Their principal effect is by virtue of their inextensibility, not shortening or lengthening under strain when bandaged to the limb in the principal planes of motion. They are roughened on each side by perforations, so that they may be securely held in position by the retaining bandage. They are not designed to serve as an accessory strengthening of an immovable splint; the strips themselves are the splint. The plaster-of-paris or other material incorporated in the retaining bandages gives to the provisional effect of the strips durability, which, of course, cannot be obtained by a simple bandage. The work of Dr. James L. Little, in the use of plaster-of-paris bandage, must not be overlooked, since he utilized this dressing for various fractures, and perfected several dressings for special fractures, notably the patella. Time will not permit of a discussion of the manifold ways that this dressing can be employed in the different fractures. It will suffice to mention the present method of treatment of fractures of the thigh, in order to afford the best illustration of the evolution of the general plan of the treatment of fractures. If we start with Desault's splint, which was crude and unsatisfactory, the first change that occurred was Physick's modification, which consisted in making Desault's splint, which reached only to the crest of the ilium, extend above to the axilla and downward below the foot, with a perineal band for extension and counter-extension. In 1819 Daniell of Georgia introduced the weight and pulley. In 1851 Buck still further modified Physick's splint, so as to do away with the perineal band, and accomplished extension of the limb by the weight and pulley, after the manner of its present use. This was a great improvement, in order to overcome shortening of a fractured limb.

Van Ingen, in 1857, suggested the elevation of the foot of the bed to permit the body to act as a counter-extending force. The coaptation splints were used by Buck, in 1861, so that the present complete and perfect method is one that is the result of evolution, the consummation of which has been accomplished by the work of American surgeons. In 1827 Nathan R. Smith adopted the principle of suspension in the treatment of fractures, and the use of the sand-bag was introduced by Hunt, of Philadelphia, in 1862. In fracture of the clavicle, Sayre has originated a dressing which is not only unique, but which is accepted as the simplest, most reliable, and most satisfactory of all the different forms of apparatus. Physick suggested the two angular splints for treating fracture of the lower end of the humerus, and Gunning and Bean the interdental splint in the treatment of the fracture of the lower jaw. Allis first called attention to the pathologic condition found in fractures of the lower end of the humerus, and suggested new principles in the treatment to prevent deformities. In 1861 Mason devised a new method of treating fractures of the nasal bones by passing a curved needle under the fragments and elevating them. In the treatment of fracture of the patella by the use of the metallic suture, American surgery can claim the operation as far as priority is concerned, since Rhea Barton wired a fractured patella in 1834, and McClellan, in 1838, and Cooper, of San Francisco, in 1861, and after him Logan and Gunn.

While American surgery cannot justly claim the priority of this operation as practiced by Lister with the modern aseptic technic, she can at least claim to having brought the operation to its present perfected technic, and can point to the fact that in New York the operation has been performed more times than it has been in any city, or in any country in the world. While the operation is not one to be recommended universally, it is an operation yielding brilliant results in suitable cases and in the hands of aseptic surgeons. The first time that fractures of the lower jaw were treated by metallic suture was by Kinloch of South Carolina. In the management of ununited fractures, American surgery stands preëminent. In 1802 Physick passed a seton between the ends of an ununited fracture of the humerus. In 1830, or twenty-eight years after the operation, Physick obtained the specimen. The use of the metallic suture was first successfully tried in 1827, by J. Kearney Rodgers, in a case of ununited fracture of the humerus.

Perforation of the ends of the bones in an ununited fracture of the tibia was accomplished in 1850 by Detmold. In 1825 Brainard introduced the operation of drilling the fragments. In 1857 Pancoast used the iron screw to accomplish the same object. In 1878 Pilcher first pointed out the correct pathology and the treatment of fractures of the lower end of the radius. Before dismissing the subject of fractures, the work of Hamilton and Stimson must not be overlooked, since they did more to systematize and to perfect the treatment of fractures in general than any other surgeons. The saw devised by Shrady for performing a subcutaneous section of the bone is an instrument worthy of the highest commendation. Excision of the superior maxillary bone, with the exception of the orbital plate, was first performed by Jameson, in 1820. The complete excision of the superior maxilla was first performed in New York, by David L. Rodgers, in 1824. Excision of the inferior maxilla was first partially and successfully made "without known precedent or professional counsel or aid," by Deadrich, of Tennessee, in 1810. Jameson exsected nearly the entire inferior maxilla in 1820. Mott exsected half of the jaw in 1821; Ackley in 1850; and Carnochan excised the entire bone in 1851. Excision of the os hyoides was performed for the first time by Warren, in 1803. Excision of the wedge-shaped piece of bone from the tibia and fibula, with osteoclasis of the bones, to correct a deformity by an osteotomy, was performed by Warren, in 1820. In 1835 Barton devised an operation which is still practiced for the relief of angular ankylosis of the knee. The entire clavicle was excised successfully for necrosis for the first time in 1813, by McCreary of Kentucky. The entire clavicle was again excised successfully for the first time for malignant disease, by Mott, in 1828. The entire scapula, three fourths of the clavicle, and the arm were excised for the first time, and also successfully, by Dixi Crosby, in 1836. This same operation was repeated by Twitchell, in 1838, by McClellan, in 1838, and by Mussey, in 1845, and since then to the present time the operation has been performed many times throughout the world.

The entire scapula and the clavicle were removed successfully six years after an amputation at the shoulder-joint by Mussey in 1837. Two thirds of the ulna was excised successfully by Butt, of Virginia, in 1825, and the olecranon by Buck, in 1842, while the entire ulna was excised by Carnochan, in 1853. The same operator excised the entire radius in 1854. Both radius and ulna were excised by Compton, of New Orleans, in 1853. Excision of the coccyx was first performed by Nott, in 1832, for the relief of severe and persistent neuralgia. Excision of a portion of the rib by the trephine, for affording drainage in empyema, was first performed by Stone, in 1862, and excision of a part of one or more ribs for the same purpose was first performed by Walter, of Pittsburg, in 1857. Beside these excisions for necrosis, suppuration, and malignant disease, much credit is due to American surgery for the part it has played in subperiosteal surgery. One of the most remarkable specimens is the reproduction of the inferior maxilla by Wood, in 1856. Langenbeck, the authority on subperiosteal surgery, said "that he did not believe a corresponding preparation really existed anywhere," and remarked that "there was not another such specimen in the whole of Europe." This was indeed a fitting tribute, from one of Europe's greatest surgeons, to the genius of one of America's greatest operators. Wood has also succeeded in reproducing many other bones in the body by the application of the same principles of subperiosteal surgery. Thus it is evident, if the first successful excision of the superior and inferior maxillas, the hyoid bone, the entire clavicle, the entire scapula, the ulna and radius, the coccyx and ribs; also trephining for relief of osteomyelitis; the most perfect specimens of reproduced bone, — be subtracted from the sum total of operative surgery upon the bones, there is little left that is not the offspring of American surgery.

In the surgery of the joints, American surgeons have accomplished brilliant work, since in the management of dislocations they have contributed much to the sum total of our knowledge. Physick was the first to perform venesection to cause muscular relaxation, in order to reduce a dislocation. This was a most valuable means, to which resort was made prior to the introduction of anesthetics. McKenzie and Smith, in 1805, reduced a dislocation of the shoulder of six months' standing by the employment of venesection. This patient had been to England and all attempts at reduction failed, and upon his return to Baltimore, the reduction was effected by relaxing the muscular system by blood-letting *ad delequium animi*. The plan is now abandoned since the introduction of anesthetics. Warren excised the head of the humerus to restore the usefulness of it after an unreduced dislocation of the shoulder-joint. The invention of plaster-of-paris jacket by Sayre, for the treatment of Pott's disease, in 1874, is one of the most important surgical discoveries of the century. The same apparatus he devised for the treatment of lateral curvature. These cases of Pott's disease, which hitherto were consigned to a distressing death, are now permanently relieved of their sufferings, and are in many cases entirely cured. Excision of the hip-joint was performed as a systematic operation, and successfully, for the first time in this country, by Sayre, in 1854. To this same surgeon is due the credit of suggesting and carrying into execution the principle of free drainage in cases of empyema of joints. In hydrops articuli, Martin, of Boston, in 1853, suggested equable uniform compression by means of an elastic bandage, and Sayre has applied the same principle by using compressed sponges. Martin, in 1877, also employed the elastic bandage for the cure of chronic ulcers of the leg. In 1826 Barton divided with a saw the great trochanter and the neck of the thigh to relieve ankylosis of the hip-joint. In 1830 Rodgers removed a disk of bone, and in 1862 Sayre perfected the operation and introduced a new principle by removing a plano-convex wedge of bone between the two trochanters, and made rotund the end of the lower fragment in order to form a new and artificial joint. In 1835 Barton removed a cuneiform wedge just above the condyle and fractured the bone, and made the limb straight to relieve angular ankylosis of the knee-joint. This operation is practically the osteotomy of the present time. In 1840 Carnochan first operated for the relief of ankylosis of the lower jaw by subcutaneously dividing the masseter muscle. In forcing open the mouth after tenotomy of the muscle, he accidentally fractured the bone, thus producing a false joint until the fracture united. Carnochan conceived then the idea of excising a wedge-shaped piece from the jaw and establishing a false joint. For the relief of this distressing condition, in 1873, Gross excised the condyle and a portion of the neck of the bone, and in 1875 Mears excised the coronoid and condyloid process together with the upper half of the ramus. Wood, in 1876, cured a patient with fracture of the cervical vertebra associated with paraplegia and brachial paralysis, by the use of the plaster-of-paris jacket. The patient, though completely paralyzed, made an excellent recovery and was able to resume his work as a carpenter.

Compound fracture may be designated as the touchstone of surgery, because a discussion of the treatment of compound fractures includes all the great principles involved in every department of the science. It embraces a consideration of cerebral, thoracic, and abdominal surgery; it includes a discussion of the great principles of antisepsis, it covers operative technic, it embraces the study of surgical pathology, it touches upon the higher departments of the science, and opens up the field where surgery must be considered, as an arena for the exercise of sound judgment, for the display of clear foresight, and for the exhibition of accurate knowledge and ripe erudition. Finally, a full discussion of this subject inevitably leads to a consideration of the progress of surgery during the present century and its precise status at the present day. In considering the management of compound fractures, I shall confine myself to the results of my own personal work as embodied in an extensive clinical experience embracing a report of 1000 cases, which I published some time ago, and since then hundreds more can be added to my list, with substantially the same result. These cases occurred within a period of a year in four metropolitan hospitals devoted to the treatment of acute surgical cases, and also in private practice. The accumulation of so vast an amount of clinical material has been attained with considerable labor. The conscientious treatment of these serious cases has been attended with a sense of great responsibility, and the results have been attained only by close attention to the minutest details in the management of each individual case. There are some points in the treatment of compound fractures that deserve special consideration, and it is only by a study of these cases in groups that clinical facts of essential importance can be established. The same plan of treatment has been carefully watched in many cases at the same time, and it has been by a process of evolution that some of the opinions which I shall enunciate have become fixed laws in routine practice. To see in one day nineteen compound fractures in the same ward with a normal temperature is not a coincidence. The number might possibly be, but the same condition in all is the result of the application of fixed principles which have been established as the result of long study and observation. To see at another time twelve cases in the same ward and all with a normal temperature is likewise no coincidence. These circumstances make it evident that the application of fixed rules is necessary to arrive at certain and uniform results.

The complete history of each one of the 1000 cases of compound fracture is carefully preserved. Each case is given in full, with the name of the patient, the date of his or her admittance to the hospital, the age, a description of the injury, the treatment in full, and the result, together with the name of the house surgeon on duty at the time as a matter of reference. It is obvious that time will not permit to discuss in detail these histories, and therefore I can only give a summary.

The general summary in the 1000 cases is as follows:

Skull	178
Nasal, malar, maxillas, and patellas	89
Arm	40
Forearm	41
Fingers and toes	97
Ilium, clavicle	2
Thigh	87
Leg	295
Fractures involving shoulder, elbow, or wrist-joints, as a result of disease or accident	39
Fractures involving hip, knee, or ankle-joints, as a result of disease or accident	85
Fractures involving carpal or metacarpal, tarsal or metatarsal joints, as a result of disease or accident	47
	1000

Now, following the example of surgical writers who have carefully tabulated the results of treatment in compound fractures, I shall eliminate all those cases in which primary amputations were performed, because they do not concern the point at issue; and I shall also, according to the practice of writers, reject all those patients who died of hemorrhage, collapse, shock, etc., within a few hours after injury. I shall also leave out cases of compound fractures of the hand and foot, as too insignificant to be classed with compound fractures of the long bones. After these deductions are made, there remain 681 cases of compound fractures, with one death due to sepsis. This gives a death-rate of about $\frac{1}{7}$ of 1 %.

In order to appreciate fully what aseptic surgery has accomplished in reference to the management of compound fractures, it is necessary to compare the results obtained prior to the introduction of antiseptic surgery. In the Pennsylvania Hospital, Norris has made a statistical report of the compound fractures treated between the years 1839 and 1851. During that time there were 116 cases of compound fractures of the leg and thigh (excluding those cases requiring amputation) with 51 deaths, thus giving a rate-mortality of 44%. In the New York Hospital during the same period there were treated 126 cases of compound fracture of the leg and thigh (excluding those cases requiring amputation) with 61 deaths, thus giving a rate of mortality of 40%. In the Obuchow Hospital reports of St. Petersburg there are 106 cases of compound fracture with a mortality of 68%. In Guy's Hospital, from 1841 to 1861, there were reported 208 cases of compound fractures with 56 deaths, giving a mortality of about 28%. Billroth reports from surgical clinics of Vienna and Zurich 180 cases of compound fractures (excluding cases of amputation), with a mortality of 31% from septopyemia. Now, after the introduction of antiseptics, a study of Billroth's table of compound fractures shows a reduction in the death-rate to about 3%. The influence, therefore, of antiseptics has caused the death-rate to fall from 68% to about 3%. In my personal report of 1000 cases, the fractures of the extremities only are compared, as has been done in all of the above tables; there is no death from septopyemia, and thus the rate of mortality from blood-poisoning is now reduced from 68% to zero. It may be said, therefore, that pyemia and septicemia, which formerly destroyed as many as 68% of compound fractures, have been practically eliminated.

The science of surgery has at last demonstrated to the world that it has fairly met these demons of destruction, and that it has conquered them. Without doubt, the means of warfare have been found in the establishment of bacteriologic laboratories, for without these institutions the discoveries that affect the happiness and mortality of the human race could not have been made. For my own part, I remained a skeptic to the germ-theory of inflammation until the Carnegie Laboratory afforded me an opportunity to work out this great problem. The reduction of the death-rate from 68%, which half a century ago was considered a brilliant achievement, and a result which was thought worthy of publication, to that of a cipher, represents what surgery has done for the amelioration of human suffering and the preservation of life. These statistics afford us the most startling and impressive lesson of what surgery has done. It has lessened suffering, it has annihilated pain, it has saved limbs, it has conquered sepsis, it has saved life. Surely nothing could be added to show more clearly the triumphant march of the onward progress of the grandest profession in the world.

Compound fractures of the skull require surgical interference which formerly was not resorted to unless in extreme cases. The intervention of operative measures has not only reduced the mortality to a very small percentage by preventing an infective process, but it also has eliminated the various nervous phenomena, such as headache, ataxia, epilepsy, insanity, and other like conditions. I have treated many hundred cases of compound fractures of the skull, and at one time collected a series of 116 cases of my own, a reference to which may give an idea of what modern surgery has achieved in the past few years in the management of this class of serious cases. Of these 116 cases of compound fractures of the skull, excluding those deaths from shock within 48 hours, in accordance with all statisticians, because these deaths were not the result of any special plan of treatment, there are two deaths which may be ascribed to sepsis. Perfection has been almost reached in the technic of the operation of trephining; but as yet there are circumstances which are not controlled by the practical surgeon, and in the study of these causes future scientific surgery must be employed. In these 116 cases of compound fractures of the skull, there were two deaths due to sepsis, which give a mortality of less than 5%.

Traumatism of the vertebral column and the spinal cord have been treated by Sayre's plaster-of-paris jacket. The utter helplessness, the intense suffering, the absolute hopelessness, the wretched discomfort, the living death make these patients objects of pity to all under whose care they come. On the other hand, the recent advances in the science of neurology, the precision of topographic anatomy, the modern researches in physiology, the introduction of anesthetics and antiseptics, the wonderful inventions in mechanical art present a most vivid picture to the modern surgeon of what surgery has accomplished by this new method of treatment. The expectant plan terminates in death, the application of well-recognized surgical principle to this peculiar class of hitherto neglected cases, has demonstrated the possibility of salvation in at least a limited number. The treatment of all these different varieties of traumatism of the spine and cord by the plaster-of-paris jacket has met with brilliant results. Before the employment of the jacket, these patients were doomed to unalleviated suffering and death. There is no reason why the same brilliant results should not follow the application of the jacket when used in connection with spinal meningitis or myelitis secondary to traumatism. Some time ago I collected thirty-three cases of recovery after unmistakable fracture of the spine, and to this list many others an be added of recent date. Cases have been eliminated in which improvement only was noted. This list is sufficiently large to attract the attention of surgeons and to induce them to employ this method of treatment in all forms of traumatism of the spine and cord. Still again, the usefulness of the jacket is demonstrated in a large list of injuries, among which may be mentioned sprains, concussion, hemorrhage, lacerations, and inflammatory thickenings. Thus it is evident that immediate extension and counter-extension with immobilization by means of the jacket, in all forms of spinal injuries, offers the most satisfactory plan of treatment that has been suggested, a plan of treatment, too, in which the results show manifest evidence of improvement, and further a plan of treatment that has been attended with a most gratifying success.

Orthopedic surgery is a department by itself, a part of which will be discussed under pediatrics. Under orthopedic surgery there are, however, a few operations that could be referred to briefly in order not to overlook the importance of the subject. Orthopedic surgery literally refers to the treatment of deformities; but the progress in this department has already passed beyond the limits that originally were set for it, and include now some of the operations in general surgery. Among the advances mentioned by Taylor are the Lorenz bloodless method of manual replacement of congenitally dislocated hips, the correction of deformed limbs by forcible movement without division of the tendons, the straightening of the kyphotic spine by great force, as suggested by Calot, the use of Sayre's plaster-of-paris jacket for correction of Pott's disease, the straightening of deformities in the limbs by osteotomy, the correction of deformities affecting the long bones by osteoclasis, the arrest of disease of the joints by excision, the removal of osteomyelitic foci in bone by excision or by the Röntgen rays, tendon grafting suggested by Dr. Vulpius, nerve suture for transference of functional activity from a healthy nerve to a paralyzed nerve, the tuberculin injection from diagnostic purposes, the extirpation of articular disease, the cure of periarticular bursitis and tenosynovitis, the healing of non-tuberculous joint disease where the etiology is dependent upon microörganisms such as are found in typhoid, pneumonia, gonorrhea, syphilis, and septic infection; the management of atrophic and hypertrophic joint disease by improvement in the physical condition and correction by mechanical means, and finally the treatment of Paget's disease of the joints, or osteitis deformans.

Surgery of the Vascular System. In the surgery of the vascular system American operators have made most valuable contributions. The innominate artery was ligated for the first time in the history of surgery by Valentine Mott, of this city, on May 11, 1818. The operation was performed for the cure of aneurism, and the patient died. The operation was essayed for the second time by Hall, of Baltimore, in 1830, and again by Cooper, of San Francisco, in 1859. Both of these cases terminated fatally. The artery was finally tied successfully for the first time by Smyth, of New Orleans, on May 9, 1864. This last operator tied also the vertebral in the same patient for the first time. Thus it is evident that the ligature of the innominate artery was first performed in this country, and it was first ligated successfully in America. Mott tied 138 large arteries for the relief of aneurism, and no surgeon in the world ever has ligated so many vessels. The primitive carotid artery was ligated for the first time successfully, for primary hemorrhage, by Cogswell, of Hartford, on November 4, 1803. Abernethy is accredited with tying the primitive carotid first in 1798, but his patient died. The first successful case, therefore, of ligature of the primitive carotid for primary hemorrhage was in America, and Cogswell had no knowledge of Abernethy's unsuccessful attempt. Again the primitive carotid was first tied successfully for secondary hemorrhage by Amos Twitchell, of Keene, N. H., in 1807, eight months prior to Sir Astley Cooper's famous case, which was supposed until lately to be the first on record. The primitive carotid was first tied in its continuity successfully, for the cure of aneurism, by J. Wright Post, on January 9, 1813. This same surgeon repeated the operation successfully on November 28, 1816. The two primitive carotids were first tied in their continuity successfully, within a month's interval, by Macgill, of Maryland, in 1823. Mott tied both carotids simultaneously in 1833, for malignant disease of the parotid gland. In 1823 Davidge first tied the carotid artery for fungus tumor of the antrum. The primitive and internal carotids were first tied simultaneously by Gordon Buck, of New York City, in 1857, and again by Briggs, of Nashville, in 1871. The internal carotid was tied successfully above and below, for secondary hemorrhage, by Sands, in 1874. Carnochan tied both carotids for the first time for elephantiasis arabum of the neck and face, in 1867. The subclavian artery in its third portion was first tied successfully, for the cure of aneurism, by J. Wright Post, of New York City, in September, 1817. The subclavian artery in its first portion was ligated for the first time by J. Kearney Rodgers in 1845. The patient died and the vessel has never been tied successfully until 1892, when it was tied by Halsted, of Baltimore. The operation was for the cure of aneurism, and the sac was dissected out by removal of the clavicle.

This is the only case in which ligation of the subclavian on its tracheal side has ever been successful, although it has been attempted in other countries; but the vessel has never been tied successfully, except in this country. The primitive iliac artery was first tied in America by Gibson, of Baltimore, in 1812. The ligation was for the arrest of hemorrhage following a gunshot wound. The patient died on the thirteenth day. Valentine Mott tied the artery successfully for the cure of aneurism, on March 15, 1827. In 1880 Sands first tied the primitive iliac, by performing first a laparotomy and securing the vessel by this procedure. The internal iliac was first successfully tied for the cure of an aneurism by Stevens, in 1812, and again successfully by Mott, in 1827, and by White, in 1847. The two internal iliacs were first tied simultaneously for the cure of double gluteal aneurism by Dennis, in 1886, upon a patient belonging to Dr. Carpenter, of Boonton. In this case a laparotomy was performed as a preliminary step. The same operator has since tied successfully the internal iliac for the cure of gluteal aneurism, for the first time, by laparotomy, as a preliminary step to operation. The external iliac was tied successfully in 1811, by Dorsey, and again successfully by Post, in 1814. Onderdonk, in 1813, tied the femoral artery successfully for acute phlegmonous inflammation of the knee-joint, and Rodger did the same operation with success in 1824. Carnochan, in the year of 1851, tied the femoral artery for the first time for the cure of elephantiasis arabum, thereby inaugurating a new principle of treatment. In addition to the various ligations already mentioned for the cure of aneurism, the invention of a variety of compression, known as digital pressure, was carried into practice by Jonathan Knight, of New Haven, in 1848.

There are many modifications of digital pressure. Wood utilized the bag of shot which was suspended above the patient, and by this means the pressure was effected by it instead of by the finger. In 1874 Stone of New Orleans first cured a traumatic aneurism of the second portion of the subclavian artery by digital pressure upon the third portion of the vessel. Martin, in 1877, suggested the use of the elastic bandage in the treatment of varicose veins, and recently Phelps, the method of the multiple ligature of the veins from the ankle to the saphenous opening. He applies some 60 ligatures to the limb, and the results of his operations have been most satisfactory.

There has been much diversity of opinion as to whom the credit belongs for the introduction of the Esmarch bandage. In the public clinics of the Jefferson Medical College, at the time of an amputation, the limb was rendered bloodless by elevation of it, and by the application of a roller bandage to it by the elder Pancoast and Gross. This was done before a tourniquet was applied. The value of this procedure was not published, and to Esmarch is due the credit of having adopted the principle with the modification of the elastic bandage, and having published it abroad for the benefit of the profession.

In the surgery of the nerves the work performed by Americans is most commendable. In 1856 Carnochan excised the second branch of the fifth cranial nerve beyond Meckel's ganglion for the relief of tic douloureux, and two years later Pancoast performed the same operation in the pterygomaxillary fossa. The mortality of the Kraus-Hartley operation for the relief of tic douloureux by removal of the gasserian ganglion in 108 cases collected by Tiffany was 22.2 %. In a later series collected by Murphy the mortality of the operation was reduced to 16 %. The recurrence of pain after the operation is observed in about 10 % of the cases. This operation is one of the most beneficent ones in surgery, as it has afforded relief from the most excruciating pain and suffering.

In 1863 Gross removed the inferior maxillary branch of the same nerve. In 1871 Sands excised a piece of the brachial plexus for the relief of persistent neuralgia of a traumatic origin. Gross for the first time excised nearly two inches of the spinal accessory nerve. The sutures of nerves, even three days after division, have been united with restoration of the function of the nerve. Operation for the relief of facial paralysis marks a new epoch in surgery of the nerves. There have been 12 cases of facial paralysis reported by Faure. In these cases the paralyzed facial nerve was exposed by dissection and then united to the hypoglossal or the eleventh nerve, and through this inosculation, motor stimulus was given to the facial, which had lost its function. The results have been most satisfactory, even though the face had been paralyzed from five months to three years.

Amputation shows a steady improvement in its results during the past century. In this department of surgery American surgeons have not only taken the initiative in the more important amputations, but they have perfected methods devised by eminent surgeons in other countries throughout the entire world. The first successful primary amputation at the hip-joint was performed by a Kentucky surgeon named Brashear, in 1806. The amputation was repeated with success by Mott, in 1824. Nathan Smith was among the first, if not the first, to successfully and systematically amputate at the knee-joint, in 1824, and the technic of this operation has been perfected by Markoe and Stephen Smith. The first successful amputation of the ankle-joint in any country was performed in 1842, by Syme, in Scotland. Triple simultaneous amputations have been performed successfully, also quadruple amputation. These are among the curiosities of surgery, and illustrate the preservation of human life in the face of the greatest danger.

In the invention of prothetic apparatus the ingenuity of the American mind has discovered a most wonderful field of operation, since in no country can be found the mechanism that is displayed in the manufacture of aluminium artificial limbs. I have at present patients who can walk and even run with two artificial limbs, and one who has artificial hands who is employed as a pharmacist.

Staphylorrhaphy was performed by Warren, in 1820, the same year, it is just to state, that the operation was performed in France by Roux, but Warren had no knowledge of Roux's method.

Excision of the tonsil was an operation placed upon a permanent and safe basis by Dr. Cox, of New York. This surgeon invented, in

1820, an instrument which included the tonsil in a ring, and then cut it by a ring-shaped knife. The guillotine principle applied to the tonsillotome was an improvement upon this instrument.

The operation for the relief of goiter is a great advance in operative work, since this was formerly one of the most serious operations in surgery. Wölfer reports 60 cases collected from Billroth, Socin, and his own clinics with only two deaths. Reverdin's mortality was only 2.8 %, Kocher's results are most brilliant, 0.2 %. Mikulicz's, 2.6 %. The treatment of cretinism and myxedema by thyroid extract is another method of cure that has been followed by recent success in a fair percentage of cases, though the use of the drug must be continued for at least two years.

The operation for rhinoplasty to restore a lost nose is one of the triumphs of the century, and plastic operations for the restoration of a partially destroyed nose is also a contribution of modern surgery. *Cheiloplasty*, or the formation of a new lip, is another plastic operation, the product of aseptic surgery. *Stomatoplasty*, or the repair of defects of the lips from contraction due to burns, and *metoplasty*, or the repair of defects of the cheeks, and *blepharoplasty*, the repair of defects of the eyelids, are illustrations of the beneficent work that surgery has achieved.

Surgery of the Genito-urinary System. In the department of genito-urinary surgery a great advance has been made by the invention of instruments to facilitate and improve the technic.

The cystoscope is an American instrument, having been invented by Fisher, of Boston, in 1824, Civiale and Heurteloup having invented their instruments in 1827. The cystoscope of to-day is one which has been evolved from the general principle of Fisher's endoscope. Otis has perfected the urethroscope by the addition of a new lamp for the electro-urethroscope. Klotz has also devised a cystoscope which is in use at the present time. Brown has devised a most useful urethral speculum for the purpose of making topical application to the canal. The Gross urethrotome, also Powell's urethral dilator, and the Otis dilating urethrotome, and the urethrotometer are instruments deserving of worthy mention. The work of Bumstead and of Van Buren in this department of surgery have already world-wide reputation. The operation of nephrectomy for the relief of malignant disease of the kidney is of American origin, since it was first performed by Wolcott, of Milwaukee, in 1860. British surgeons give the credit of this operation to Simon of Heidelberg; but he did not perform his operation until 1869, or nine years after Wolcott's operation.

Nephrectomy was first performed in America for gunshot wound of the kidney by Keen in 1887, and again two months later for the same reason by Willard, and still again for the same cause by Price, successfully, in 1888. The first successful operation for the relief of extroversion of the bladder was performed in New York by Carroll on April 13, 1858. Pancoast performed the same operation successfully the same year, and Ayres in 1859. All of these cases antedate the British successes of Woods and Holmes, although there are two operative failures reported by Crook and Lloyd in London in 1851. In plastic surgery of the urethra another brilliant triumph has been made by American surgeons. In 1892 Alexander succeeded for the first time in the history of genito-urinary surgery in making a new urethra, the retentive powers of which were perfect in a case of complete epispadias in the female. There have been 12 cases in all of complete epispadias, in none of which heretofore has the urine been completely under the control of the patient. Physick did an internal urethrotomy by a concealed lancet, and Stevens, in 1817, was the first surgeon in this country to perform external perineal urethrotomy. He revived the operation, which had fallen into desuetude, since at the close of the last century the mortality was so great that the operation was practically abandoned. Prior to 1840 the operation was performed in this country by several surgeons; notably, in 1820 by Jameson, in 1823 by Rodgers, in 1829 by Warren, and later by several surgeons connected with the New York Hospital, among whom may be mentioned Hoffman, Post, Watson, and also by Alden March, of Albany, and Wood, of New York City. Without doubt the operation has reached its present state of perfection through the labors of Gouley, who suggested the whalebone guide, the tunneled catheter staff, and the beaked bistoury.

Hypertrophy of the prostate is a distressing and fatal condition which modern surgery in the course of its development has to a certain extent relieved, if not cured, in a large percentage of cases. It is one of the triumphs of the art within the period of time of which an inventory of the present surgical operations is taken. A review of the operation for the relief of hypertrophy of the prostate would be incomplete without an acknowledgment of the work of Reginald Harrison, Alexander, and White. As regards the benefits which have accrued to these sufferers from castration, it may be stated that White has shown that 66 % or more have return of the power of micturition, most of them a relief of the cystitis, and nearly all freedom from pain. In a series of 98 cases with 7 deaths estimated by White, the mortality of the operation was only about 7 %. This is after eliminating a few deaths which had no relation to the operation itself. These figures are striking, and as the time goes on and diagnosis is improved and technic is perfected, and early operations are resorted to, the percentage of alleviation of symptoms and of mortality will be even better than those just mentioned. Castration will never take the place of modern prostatectomy with its present low mortality, and which is gradually improving each year from about 6 % as reported by Mayo.

The operation for suprapubic prostatectomy was first performed in this country by Belfield, in October, 1886. Prostatectomy is an operation, the technic of which has been devised in recent years, and it gives great comfort to the patient and saves life. Murphy has reported 34 consecutive cases without a single death due to the operation. This operation has been greatly improved upon by the use of Gouley's prostatectome, which facilitates the removal of the gland.

In lithotomy American surgeons have achieved brilliant results. McDowell did 32 lithotomies in succession without a death. Dudley performed over 100 consecutive operations without a fatal case. In 1846 Willard Parker removed a calculus from the bladder by producting a rectovesical fistula; and subsequently performed this operation for the cure of chronic cystitis, and in 1861 Bozeman did this same operation to relieve a chronic cystitis in the female. In 1836 Physick removed over 1000 calculi. These brilliant results in lithotomy are most remarkable when it is considered that there was a time in the medical history of this country when a patient actually made the pilgrimage across the ocean in order to secure the services of a surgeon to perform lithotomy.

Litholapaxy is an operation that was introduced by Bigelow in 1878, and has been the means of saving thousands of human lives within the past quarter of a century. It forms one of the most prominent advances in surgery that has distinguished the century. By litholapaxy is meant the crushing of a stone in the bladder with an instrument called a lithotrite and the immediate rapid evacuation of the fragments from the bladder by a syringe especially made and adapted for this purpose. It is a matter of surprise and interest that Bigelow's entire apparatus for litholapaxy remains essentially the same to-day as it did a quarter of a century ago, which demonstrates how complete the mechanism is in all its minor details. Keyes has made some great improvements in litholapaxy, thereby reducing the mortality of the operation, among which may be mentioned in the list of improved instruments the modern evacuating-tube, the alteration in the mechanism, and other improvements in the technic of the operation. Keegan performed Bigelow's operation 59 times in children, with one death, and Freyer performed it 49 times without a death. The record of Bigelow's, or the American operation of litholapaxy, has certainly won for itself a fixed place in the annals of surgery.

Rupture of the bladder was operated upon successfully by a laparotomy by Walters, of Pittsburg, in 1862, but to Sir William MacCormack is justly due the credit of establishing this operation.

Rupture of the bladder has been successfully treated by modern surgery. Formerly these patients nearly all died; thus Ullman's statistics show only 22 recoveries in 237 cases, and in 143 intraperitoneal ruptures only two patients recovered. If the patients are operated upon early and with aseptic precaution, the prognosis is as brilliant as it was formerly forlorn.

Tumors of the bladder have been removed in recent years, and this operation marks an important epoch in this department of surgery. In benign tumors the mortality is about 10%, while in malignant tumors the mortality is 25%. These statistics are certain to improve in the future. Intravesical cauterization with the operating cystoscope for small tumors of the bladder has met brilliant results; thus Nitze had 119 cases without a death.

In surgery of the kidney great progress has been made. The floating kidney is successfully anchored, gunshot wounds of the kidney cured, renal calculi removed, suppuration in the pelvis of the kidney arrested, removal of the kidney itself undertaken for tuberculous and other diseases, and tumors of the organ excised. These are among the achievements of modern surgery, to relieve conditions which were uniformly fatal in pre-anesthetic and pre-antiseptic days.

Nephrotomy for the extraction of calculi has been performed and in aseptic cases has a mortality of only 2.9%. If infection is present the mortality reaches 23%. If nephrectomies for the past ten years are taken, irrespective of the disease for which the operation is performed, surgery has obtained a great victory, since in 365 cases of lumbar nephrectomies there was a mortality of 17%, and in 165 cases of abdominal nephrectomies there was a mortality of 19%. These figures indicate what surgery has accomplished in cases heretofore fatal.

Nephrectomy for the relief of tuberculous kidney marks a great advance in surgery of recent years. Statistics show that in 22 nephrectomies, 16 patients recovered, or about 70%. In another group the recoveries were from 12% to 33%.

Aneurism of the renal artery has been operated upon by Albert, Hahn, and Keen, and all of their patients recovered.

Wounds of the ureters have been successfully sutured, a triumph of modern surgery, and the ureter itself catheterized for diagnostic purposes.

Malignant tumors have been treated with brilliant success in recent years. In fact, so much so in certain varieties that the term seems almost a misnomer. In the management of malignant tumors, American surgeons have displayed great ability. The early work of Warren, of Boston, was among the first attempts systematically to collect and study neoplasms from a clinical point of view. The writings of Gross upon tumors demand more than a passing notice, while the contributions of Shrady and of Mudd to cancer of the tongue are most exhaustive.

Malignant tumors are now often cured by radical operations. A century ago these cases presented a frightful mortality. In the course of the development of surgery, owing to anesthesia and antiseptics, more radical operations are permissible, and cures are now effected where formerly death was the inevitable result. The study of sarcoma is fraught with great interest on account of the meager knowledge, and of its great importance owing to the fact of the terrible mortality which attends the disease. Sarcoma of bone inevitably terminates in death, and its early recognition and its complete removal are subjects which are worthy the profound study of the surgeon. Sarcoma, in the large majority of cases, is a disease more deadly in its nature than any other variety of malignant tumor. Its unprecedented rapidity of growth, its widespread metastases, its insidious development, its uncertainty of early diagnosis, its absolute certainty to kill, make this disease a subject of paramount importance. In this address a study of the varieties, the etiology, and the diagnosis has no place. The prognosis concerns us only.

The prognosis in sarcoma is as gloomy as can be imagined. It is a disease which destroys life rapidly unless arrested by amputation. The prognosis may be modified as regards time by the situation and the particular cell variety of the sarcoma. In whatever way we look at the prognosis it is serious. On the other hand a radical amputation may rescue a patient's life, even in the cases of the most malignant variety. I shall refer to some statistics already published by others, and present the result of my own personal work, as evidence of the progress which surgery has made within the past quarter of a century. For purposes of illustration the malignant tumor known as sarcoma will be first considered.

Sarcoma of glands is a malignant tumor concerning which reliable statistics are very meager. The great English authority, Butlin, states that he fails to discover a single case of permanent recovery after operation. In my list there have been 12 cases of sarcoma of the glands up to 1895, the subsequent histories of which are all known. There have been some cases since that date; but sufficient time has not elapsed since operation in some of the cases, and unreliable histories in some other cases, prevent the tabulation of these cases subsequent to 1895. The principle of cure is the essential feature, and the data up to 1895 have been most carefully investigated. This may be said of all the cases of sarcoma. In these 12 cases, recovery occurred in every case but one, thus giving 83.3% of permanent cures beyond the three-year limit of time. In these 11 successful and permanently cured cases of sarcoma of the glands, there were some which were very large. In two the tumors involved the neck, one of which was larger than a child's head, necessitating a deep and dangerous dissection, which exposed the large cervical vessels. In another case the tumor was situated about the femoral vessels. Some of the tumors were removed in the presence of alarming hemorrhage and involved a most formidable operation. Thus, in sarcoma of glands with 100% mortality, the permanent cure amounted to 83.3% in the 12 cases.

Sarcoma of bone in previous years has been attended with a frightful mortality until surgery, with modern technic, has come to the rescue of these unfortunate sufferers. Butlin records 78 cases of subperiosteal sarcoma, of which the results in 28 cases were unknown, and in 6 cases more the patients had not reached the three-year limit of time, which leaves 44 cases in which the full subsequent histories are known. Of these 44 cases, 14 died of the operation and 29 from recurrences, which leaves but 1 permanent cure in the 44 cases. There are thus 78 cases in which the operation was performed; 14 of the patients died from the immediate effects of the operation, which gives 18% mortality for the operation itself, and of the 44 patients whose full subsequent histories are known, there was but 1 permanent cure, or 2%. In my list I reported 21 cases of subperiosteal sarcoma of bone in which an operation was performed, 1 of which was an amputation of the hip-joint, and the patient died from the immediate effects of the operation. This gives only 5% mortality for the operation itself. The histories of 4 are unknown. In the remaining 17 cases of the original 21 cases in which the results are known, there are 3 deaths, 1 of which has just been referred to as a result of shock, and 14 cures beyond the three-year limit of time, which gives 82% of permanent cures. This is in marked contrast to Butlin's statistics, which records only 2% of permanent cures.

Sarcoma of the breast is a disease that formerly was most fatal. Modern surgery has accomplished much in reducing the terrible death-rate. Butlin, in his book on malignant disease, gives no results either as to mortality or as to permanent recoveries. Williams, in his book, reports 10 cases of sarcoma of the breast, in which no deaths occurred in consequence of the operation itself. The subsequent histories of only 2 out of the 10 cases are known. Death occurred in the 2 cases within 2 years from the date of the operation. The percentage of permanent cures, therefore, amounts to zero, since no patient recovered so as to be free from the disease for a period of 3 years. It is to be regretted that nothing is known of the 8 cases since among the list; there may be some cases of permanent cure. It is unfortunate that these cases have been lost sight of, since no statistics of permanent cure can be recovered unless the result is known. Gross reports 91 cases operated upon, of which 12 were permanently cured, giving 13% of permanent cures.

I operated in 6 cases of sarcoma of the breast, in which no death occurred in consequence of the operation itself. The subsequent histories are all known. Four of the 6 patients were permanently cured, and the remaining 2 died from a return of the disease. This gives 62⅔ % of permanent cures in sarcoma of the breast.

Carcinoma of the breast affords a striking illustration of a disease over which surgery has gained a decided victory. There is no more brilliant example to show the progress of surgery during the past century than is found in a study of cancer of the female breast. The necessity of an investigation of carcinoma of the breast can be estimated when it is considered that in England alone there are 7000 deaths annually from carcinoma, and that there are 30,000 patients suffering at all times in that country from this affection, of which number a large proportion involve the breast. When it is considered that 50 % of the cases of carcinoma of the breast die within three years, and that a third die within two years, and that of all of the tumors affecting the breast, 80 % consist of carcinoma, some idea can be formed of the overwhelming interest and paramount importance of this subject. The mere fact that carcinoma causes more deaths in the United States in one year than the sum total of deaths due to erysipelas, tetanus, hydrophobia, lighting, typhlitis, gunshot wounds, joint disease, together with well-known surgical affections, conveys at once an idea of the wide dimensions of this subject. Carcinoma causes nearly half as many deaths in a year in the United States as are caused by accidents and injuries of all kinds and descriptions.

Dr. Billings has demonstrated by statistics that carcinoma is a disease which is slowly increasing, and that it is a cause of a larger proportion of deaths in nations which have reached the highest state of civilization. For example, in the United States in a year there were over 13,000 deaths from carcinoma, of which there were twice as many deaths among females as among males. There were 1387 cases of death from carcinoma of the breast alone in this country during the year 1880, and since then statistics show the disease is still increasing. The mortality of this disease, if left unoperated upon, is nearly 100 % at the present time, just as it has always been. The mortality of the patients operated upon formerly was considerable, and the percentage of permanent cures very small, while now the operative mortality is very small and the percentage of permanent cures is very high.

I shall refer to my own personal experience, the results of which I have already published, adding, however, that the results in the more recent cases are even better; but the data in full are not possible to collect for many reasons, and chief among these is the three-year limit of time. I have collected within a given period a series of

116 cases of tumors of the breast, 19 of which were not operated upon, leaving 97 cases in which the breast was amputated. In the 97 cases of amputation there was but one death, thus giving a mortality of a little over 1%. The one fatal case was due to the presence of hemophilia and is a death that might have occurred in connection with any other operation, no matter how insignificant in character. This death can therefore with propriety be excluded as far as bearing upon the mortality of this special operation, and if so, there is an unbroken series of 96 consecutive operations without a death. In addition to the reduction of the mortality of the operation from as high as 23 % recorded by Billroth to a zero, there was no case of pyemia, septicemia, or erysipelas of the 97 cases of amputation of the breast. Twenty-three cases of sarcoma and other tumors than cancer must be eliminated in order to compute the percentage of permanent cures of pure carcinoma of the breast. These cases of sarcoma of the breast are discussed in connection with the subject of sarcoma. Of the 74 cases of pure carcinoma of the breast, the subsequent histories of 41 are known. Three of these patients have not reached the three-year limit of time, although they are still alive and free from the disease; there remain 38 cases, therefore, of pure carcinoma of the breast in which the full subsequent histories are known. In these 38 cases there are 17 cases in which a permanent recovery has taken place. This gives 45 % of permanent cures. Among these 38 patients whose histories are known there were but 2 local recurrences, which gives but a little over 5 % of local recurrences. Since the publication of this series I have had 15 consecutive cases of pure carcinoma of the breast with no mortality from the operation itself. Of these 15 cases, 1 died several weeks following the operation from hemophilia, in which the major joints were filled with blood, and the greater part of the body was affected with subcutaneous hemorrhages. Two of the 15 have not yet reached the three-year limit of time. There are, therefore, 13 cases in which the full subsequent histories are known; 2 of these patients died from a recurrence of the disease and 1 from hemophilia, as stated before, and the remaining 10 have passed the three-year limit time. This gives 77 % of permanent cures in cancer of the breast in the last 15 consecutive cases. I believe the last 15 consecutive cases will yield even better results. At all events, the mortality was zero and the permanent cures seem likely to be higher than 77 %. Modern surgery has much of which to be proud in connection with amputation of the breast, since the frightful mortality of a century ago has been replaced by a steadily increasing percentage of permanent cures. In the future even the present favorable percentage of permanent cures will be increased as early and more radical operations are practiced.

In 1820 Sidney Smith, the great literary genius of his time, made use of the following phrases in the *Edinburgh Review*, which furnishes somewhat amusing reading in the light of to-day: "Americans have done absolutely nothing for the sciences. . . . In the four quarters of the globe, who reads an American book? What does the world yet owe to American physicians and surgeons? What new substances have their chemists discovered?" The contradiction of the first phrase that "Americans have done absolutely nothing for the sciences" is found in the brilliant and wonderful achievements performed by them, as recorded in this address, by which millions of human lives are saved. "In the four quarters of the globe, who reads an American book?" To such a challenge facts reply louder than words. Were you to take from the world's medical literature, alone, all that has been contributed by Americans during the past century, the result would be astonishing and the loss incalculable. "What does the world owe to American physicians and surgeons?" To this challenge the record of new operations, bold and undreamed of, the invention of new processes, the introduction of new instruments and methods, all of which I have endeavored to outline rapidly in this address, is the abundant reply to this unique interrogative viewed in the light of to-day. "What new substances have their chemists discovered?" The sufficient answer is, "anesthesia," which one discovery apart from all the other noteworthy ones which our chemists have made, places the civilized world under unspeakable obligations to America. Anesthesia is by far the greatest and most far-reaching discovery of the century, a gift to the world which cannot be estimated, a direct benediction from God upon mankind for the saving of life and the escape of humanity from pain.

In a review of the statistics that have been presented, one prominent fact stands out in clear and bold relief, and that is, that all along the line constant and marvelous improvement has been made in the science of surgery. To this statement there is not a single exception in the entire surgical domain. Everywhere and in every department there has been uninterrupted progress — a progress which has not been hindered or hampered by the loss of any past discovery.

In nearly all the other arts and sciences there is something which has been lost. They have advanced, indeed, most gloriously, and their present development is wonderful in the extreme; yet each one has dropped some good thing by the way which can never be recovered. Their votaries in bygone centuries possessed some secrets in methods and processes which not only died, but evidently were buried with them. By these they secured certain remarkable results which their modern followers, try as they may, are unable to reproduce. Thus in the art of painting, sculpture, architecture, mosaics, pottery, and physics, there are what we style "lost arts," as Wendell Phillips so eloquently has told us, contributions from which have come down to us from the past, which cannot be duplicated in the present. In painting, for instance, the superb coloring of the ancients in their Tyrian purple, and the brilliant scarlet which fades not in centuries. In sculpture, the majestic chiseling of Michael Angelo, that crumbles not in ages. In mosaics, the fusing of gold and glass so that the yellow of the precious metal retains its perfect color. In pottery, a variety of delicate tints and graceful forms which baffle the skill of the potter in these modern times. In physics, the pyramids of Egypt — how were the huge blocks of stone ever carried to the summit, some of them nearly 500 feet above the desert sands, to be laid there in courses which are absolute in regularity and evenness? How were the gigantic monoliths of Baalbec cut out of the mountains and set high in the walls of the Temple of the Sun? How were the mighty obelisks, 16 centuries B. C., transported from the distant quarries, and then set on end with perfect exactitude? Or how was the massive capital, weighing 2000 pounds, ever lifted to its place on the top of Pompey's Pillar, 100 feet in the air? All these are forcible illustrations of arts which have been been lost.

But in the science of surgery it is wholly different, and there is no such counterpart. No operation, no invention, no discovery in this domain that was worth the keeping has ever been lost. The truth is, surgery, as it is practiced nowadays, is so completely a modern science that it does not rely upon anything in the distant past for its present or future development. That distant past was dark with horrible things which may well be tumbled into oblivion. It is only a few decades ago that surgery emerged from the black period of ignorance and cruelty and took to itself a new face and another spirit and form. At once it began its onward march, which speedily became a triumphant one, difficulties giving way before it, obstacles being overcome, every step an advance, with here and there a milestone set up to mark some distinguished feature in the splendid progress. By this new science diseases, which were formerly attended by 100 % of mortality, are now accompanied by almost 100 % of recoveries. In fact there is no surgical disease whose mortality has not been reduced. No other science can show such brilliant achievements, and no other science can demonstrate its ability to save so many human lives or to ameliorate their condition. We live in an age that is marvelous for its discoveries and achievements, but in no department of science have greater changes been wrought or more brilliant results accomplished than in surgery. It would now seem that we had almost reached the goal. There are but few surgical diseases which our art in its present condition of development does not cure. There are but few operations in point of number that remain for succeeding generations to discover. There is still little to gain in the technic of asepsis and anesthesia, and beyond the improvement of existing operative methods there is but little to expect. The science of surgery has accomplished a great work — one of the greatest in the history of mankind. And when we consider the vast number of surgical diseases which are now amenable to cure, and the very limited number remaining for which the surgery of the future is to discover ways and means of treatment better than those to which we have already attained, we can realize that we stand on the heights of a great profession — a profession which but a century ago was crude, undeveloped, and uncertain. If there are higher heights to be reached in the science of surgery, and doubtless there are, we may rest assured that the vast and ever-increasing wealth of this great country will be utilized toward their attainment. Humanity demands this, and this country will never be behind any nation of the world in earnest efforts for the promotion and development of a science whose special aim is the relief of physical suffering, and the preservation of human life.

It is fitting on an occasion like this, when a national celebration is in progress, that the attention of this Congress should be directed to the part which our own country has played in the evolution of this great science. This part is best set forth and realized by a study of the facts recorded in this address. The question, however, as to what has been the inspiring motive, and what has been the controlling influence, must be sought in the life-history and habits of the people.

The impartiality and promptitude of the American mind have enabled it to seize with alacrity upon the best in every department of science and art, wherever found, regardless of the source from which it emanates. Accordingly, American surgeons all through the past century have busied themselves in reaping a generous harvest from every nation that had any good surgical idea, method, or appliance to offer, and have gathered in abundant sheaves with rejoicing, serenely indifferent as to the particular field which produced them. What mattered it to them whose hand sowed the seed, or under what influences it was brought to maturity, so long as the grain itself was desirable and could be secured for the American garner. A precisely opposite spirit has prevailed in some other lands; thus, during our colonial days, when Great Britain and France were easily foremost in surgical attainment, so bitter was their rivalry, so intense their national jealousy, that neither would adopt anything, no matter how good or valuable, which had originated with the other. Of late years this same prejudice, this unwillingness to indulge in a sensible reciprocity, has been manifest between France and Germany, to the great detriment of surgery in each of these rival countries. As an apt illustration, characteristic of the difference between the English and American spirit in this regard, may be cited the fact that in 1823 the writings of one of the great French surgeons, Desault, the most noteworthy contribution to the surgical literature of the world then published, had never been translated for the use of British surgeons. No Englishman had the courage or willingness to demean himself by so doing, since he would thereby acknowledge that some good thing might come out of France. Yet at that very time, Smith, of South Carolina, rejoicing as one who had found great spoil, was busily engaged in putting Desault's works into English for the benefit of the surgeons of America.

So in this great triangle of nations formed by England, France, and Germany, the surgical knowledge and suggestions of each remained within its own walled domain, untouched by the others; on the contrary, in a pleasantly independent spirit, and having no unfortunate jealousies to cherish, America reached her eager hand over the separating wall, and freely and gratefully laid hold upon whatever she considered best in the surgery of those and other nations, appropriating to her own use, for the good of humanity at large, as many of their principles, theories, discoveries, methods, and appliances as she considered it worth her while to take. Availing herself of these factors, utilizing them as stepping-stones, and combining them with the wonderful achievements of her own inventive genius and skill, she has rapidly risen to that illustrious height in the surgical world which she so grandly occupies to-day.

It goes without saying, gentlemen, that within the past decade, America, without any effort of her own, without the least self-seeking, but through the force of her national greatness — moral, intellectual, physical — has come to the front as a world-power among the nations of the earth. She now ranks second to none as an important and controlling factor in the congress of nations, and when she speaks, her voice commands the attention of a listening world. In this regard her science of surgery has kept even pace with her political advancement upon the powers. At the present time her surgeons are not outclassed by those of any other country, while in her contributions to the general literature of surgery, she stands unsurpassed. It is an actual fact, if you were to strike from the notable surgical achievements and writings of the world what has been contributed by America during the past few decades, there would be left but little of new and original work for the older nations to claim as their own.

There are many things which combine to explain the prominent position which America has taken during the past century in the consummation of this great work. Chief among them may be mentioned the innate courage which our Puritan ancestors possessed. The undaunted bravery which enabled the people of the Mayflower, and others of kindred heart and mind, to cross the great unknown oceans and to settle in the primeval forest for the sake of liberty, has infused itself into the American spirit and has qualified Americans to attempt and to perform daring deeds in surgery. There is no science that calls for greater fearlessness, courage, and nerve than that of surgery, none that demands more of self-reliance, principle, independence, and determination in the man. These were the characteristics which were chiefly conspicuous in the early settlers of this country. And it is these old-time Puritan qualities, which, descending to them in ordinary generation, have passed into the surgeons of America, giving them boldness in their art, and enabling them to win that success in surgery which now commands the admiration of the civilized world.

Permit me to sum up in a few words the wonderful achievements of surgery during the century which has gone. What has this great science, so young comparatively and yet so strongly and splendidly developed, accomplished in its onward march? Among the blessings which it has brought to the human race may be mentioned these:

The annihilation of pain during surgical operation.
The elimination of sepsis after operations and injuries.
The eradication of physical suffering.
The restoration of sight to the blind.
The recovery of hearing to the deaf.
The return of lost functions to organs and glands.
The aseptic repair of injured parts.
The relief of the crippled and lame.
The restitution of speech and consciousness.
The return of activity to paralyzed members.
The removal of malignant disease.
The restoration of reason to the insane.
The correction of bodily deformities.
The alleviation of pain in disease.
The reaction from shock and collapse.
The cure of lockjaw and other infective processes.
The intervention of relief in intestinal perforation.
The extirpation of tumors from glands and cavities.
The cure of diseases and injuries of internal organs.
The resection of diseased viscera.

The excision of joints and necrosed bone.
The amputation of diseased members.
The cure of aneurism.
The removal of cerebral and spinal neoplasms.
The reduction of mortality in all surgical diseases.
The entire removal of mortality in some surgical diseases.
The restoration of health and reason.
The salvation of human life.

Surely, Mr. President, and fellow members of the International Congress of the Arts and Science, the great science to which we have devoted our talents and our lives, the science which kindles our enthusiasm, and of whose achievement we are justly proud, our science of surgery during the past century has come as a benediction upon the human family, second to none which the century has spoken. Its benefits cannot be measured by words, or realized in thought. We are apt to speak of it as a human achievement. In one sense, so it is; but it is come in the orderings of an all-wise Providence; and with grateful hearts we acknowledge it as a gift and blessing from the Almighty Father to His suffering children in the world.

SHORT PAPERS

Dr. Carl Beck, Professor of Surgery in the New York Post-graduate Medical School, and Chairman of the Section of Surgery, presented an interesting technical paper "On the Technic of Urethral Dislocation in Hypospadias and in Other Defects and Injuries of the Urethra."

Professor Johannes Orth, of the University of Berlin, presented the following short paper on "The Morphology of Cancer and the Parasitic Etiology."

Gentlemen, — In answer to the request of your president, Dr. Carl Beck, I address you to-day concerning Carcinomatous tumors. I can tell you nothing new, but perhaps it will have a certain interest for you to hear the views of a pathologist who agrees in general with the greater number of German pathologists in regard to two questions which read:

I. What are the morphologic characteristics of cancer?

II. What is the present position of the question of its parasitic etiology?

I

As regards the first question there can be no doubt that the characteristic and determining elements are the cancer cells, and the cancer cells are nothing else than epithelial cells. They are epithelial cells not only as regards their structure but as regards the character of their protoplasm and their nuclei. Not only epithelial as regards their biologic activities, they are also epithelial as regards their origin.

There is no metaplasia of connective tissue, or other cells into epithelial cells, into cancer cells. Of course one sort of epithelium can change into another, cylinder cells into squamous epithelium, squamous cells into cylinder cells, but an epithelial cancer cell is never formed from a connective tissue cell.

In primary cancers the fact of the direct origin of cancer cells from preformed epithelium is, however, difficult to prove, as the growth of a cancer is not the same, nor is its primary origin. I, indeed, believe that there are cancers in which the conversion of preformed epithelial cells into cancer cells proceeds continuously in the surrounding tissues at the edge of the primary tumor, that there are multicentric cancers, not only in the sense that at the same time cancerous transformation occurs in numerous neighboring places, but also in the sense that one place becomes carcinomatous later than another. I realize, however, that many cancers are unicentric, that they originate from a single cell complex and possess only interstitial, no appositional growth. Previously we assumed without proof a cancerous transformation of preformed epithelium wherever epithelial and cancer cells came into contact. That such a view is not permissible has been justly pointed out by Ribbert; as it is possible that cancerous epithelium has grown against preformed epithelium and secondarily displaced this; but we cannot go so far as to explain the relation of cancer cells with normal epithelium which we find at the edge or in the immediate neighborhood of a cancer in this way, although we can often show positively in serial sections that an isolated growth of preformed cells occurs in which the quality of the cells show a certain variation from the appearance of the mother cells. That in such cases a special sort of karyomitosis occurs, similar to the mitosis of a fertilized ovum, I have not been able to convince myself, but without doubt changes in the behavior of the cells towards stains occur, as may be shown most easily in the cancers of the gastro-intestinal tract. Not every phenomenon of growth in preformed epithelium can, however, be looked upon as the beginning of cancerous transformation, for there occurs at the border and in the neighborhood of cancers and of other rapidly growing tumors, cell division, as well as glycogen formation, which are only the expression of purely hyperplastic processes, but when a distinct conical invasion of the underlying tissues, with transformation of the cell-body, can be demonstrated, we may well think of primary cancerous transformation.

The origin of cancer cells from preformed epithelium can, of course, be recognized most easily in very young cancers and Dr. Borrmann, Ribbert's assistant, who collected such cases and investigated them carefully did a great service. In his recently published work he brings proof of the epithelial origin of cancer cells in young primary cancers.

Secondary cancers of all sorts give especial support to the view that all cancer cells originate from epithelial cells in regular generation; because the numerous mitoses which cancer cells show let us see how rapidly they are divided; so rapidly that the entire growth of these secondary tumors may be completely explained in this way. The occurrence of the first cancer cells in the lymphsinus of the lymph glands, or the appearance of cancer cells in blood-vessels, shows us that metastatic cancer cells are the basis and starting-point of new cancer nodules. It can be shown most strikingly by study of serial sections of cancers of embolic origin in the lungs or the liver that cancerous growth in the neighborhood of the vessel always takes its origin from a cancerous penetration of the wall. There is no auto-infection through the uninjured vessel wall of the connective tissues surrounding the walls of the vessel, but a continuous connection between the embolus and the peri-vascular cancer; the embolus by increase of its cells has grown through the wall into the surrounding tissue.

The behavior of the parenchyma cells at the seat of the new tumor gives especial support to the view that all cells of the secondary cancer have arisen from displaced cells of a previously existing cancer. As we may show especially in cancers of the liver, the local cells, the liver cells, have absolutely nothing to do with the formation of cancer cells. They remain entirely passive, and are pushed aside by the uninterruptedly dividing cancer cells, they become atrophic and finally vanish completely.

All these facts show that the epithelial cells are the essential elements of cancer. But they are not only the essential but the *only* essential element. The tissue which in addition is present in cancers, stroma, has no bearing on the nature of cancer.

There are carcinomatous tumors without any stroma. In the so-called lymph vessel cancers, that is, the growth of cancer cells in the lumen of lymph vessels, as known in cancers of the lungs, of the uterus, and of other parts, extremely dilated lymph spaces can be filled, for long stretches, entirely by cancer cells without a trace of stroma being present. In other cancers the local tissue of the part may take the place of stroma. Thus there are cancerous growths in the lung in which the alveolar lung framework fills immediately the place of cancer stroma. Thus, in intro-vascular or infiltrating carcinoma of the liver, the liver tissue itself, liver cells, and interstitial connective tissue form the stroma. In other cases, however, the cancer stroma is a new formation, as is shown most plainly in many cancers of the ductus thoracicus in which the lumen of the dilated duct contains not only cancer cells but also stroma, which consists, of course, of completely new formed tissue, but of tissue which has originated from the nearest local tissue, namely, the vessel-wall.

Professor Williams, of Buffalo, has in my institute at Göttingen studied such a case in which elastic fibers were present in the stroma, the connection of which with the elastic tissue of the duct wall could be demonstrated.

This shows that the stroma is throughout an accessory unimportant, unessential component of cancer; although in certain cases the stroma is of importance in determining the character of the cancer; but that a scirrhus is not different in its nature from a soft medullary cancer is shown most clearly by the fact that the edges and the metastases of scirrhus may be entirely of a soft, medullary character.

If, as we have said, the essential character of cancer is the uninterrupted origin from preformed epithelium, from the scientific standpoint all cancers must bear, according to the customary nomenclature, the name of epithelioma. To distinguish it from other epithelial tumors it may be designated malignant, destructive, or heterotopic epithelioma; for the distinguishing characteristic is, that in cancer, epithelial cells occur in places where epithelium does not belong. Where there is a sharp line between the epithelial and non-epithelial parts of an organ, as in the gastro-intestinal tract (muscularis mucosae), the heterotopia of the cancer cells is easily shown. In other places it is the occurrence of connective tissue inclusions, especially of elastic and colloid fibers in masses of cancer cells, which proves that cancer cells are present where they do not belong; that they have forced their destructive way into other tissues.

Another result of the epithelial nature of cancer is, that the forms of cancer must be determined by the behavior of epithelial cancer cells, and it is of especial importance that however cancer cells may differ from normal epithelium (anaplasia of Hansemann) still, on the whole, the cells of the primary tumor, as well as those of the metastases, retain a definite character in their arrangement as well as in their morphologic and in their biologic behavior.

Thus, we may distinguish two groups of heterotopic epitheliomata:

(1) Those with a typical arrangement of the cancer cells;

(2) Those with an atypical arrangement.

To the first group belong (*a*) cancers (usually formed of cylinder cells) arranged after the gland type (Adenomata) which possess gland canals and complicated glandular structure, and which, especially in the gastro-intestinal tract, not infrequently produce a mucoid secretion. (*b*) Cancers which resemble epidermis in the form, character, and stratification of their cells, and which have borne for a long time the name of cancroids. It is specially important, for the doctrine that all cancer cells of metastatic growths arise from cells of the primary cancer, that in this first group of cancers, in adenoma as well as cancroids, the cells in the metastases show the same form and the same arrangement or stratification as those of the corresponding primary tumor.

The second group is composed of cancers whose cells are grouped irregularly in heaps and cords which show no typical arrangement. The cells also show less marked peculiarities, although we may say that they differ according to the individual organs from which the original tumor may have developed. I might designate these cancer forms with the word which forms the root of cancroid, namely, Cancer.

There are, however, mixed forms and transition forms between these particular types.

II

These facts give us important bases for the second principal question, that regarding the parasitic nature of cancer; for, if the primary cancer with all its metastases is nothing more, histologically and histogenetically, than a great family of epithelial cells, which all have a common origin from preformed epithelium; it is impossible that a parasitism can exist here in the same way as in the well-known parasitic diseases, such as the pyemic diseases or the infectious granulomata. Pus is a local formation, whether in a primary or a metastatic abscess, tubercles, gummata, nodules of leprosy, and actinomycosis, etc., are purely local formations wherever they grow, whether they are primary or secondary. No cellular connection exists between primary and secondary abscesses, between primary and metastatic tuberculous masses.

That pus, tubercles, etc., may arise, it is sufficient that pus cocci, tubercle bacilli, etc., arrive at a certain place. For the formation of secondary cancer it is absolutely necessary that cancer cells from the primary tumor, or from a secondary tumor originating in the same way, arrive at the spot, and continue their growth. In secondary cancers there is an effectual transplantation of cancer cells, in suppuration, tuberculosis, etc., a transplantation of parasitic organisms, which do not themselves constitute the new lesion but cause definite phenomena in the local tissue without any coöperation of tissue from the primary lesion. Thus, there exists between these two groups of processes an essential difference, and we cannot conclude that because parasites play a rôle in abscesses, tuberculosis, etc., that this must necessarily be the case in cancerous tumors. We can, however, say that if parasites play a rôle in cancer, these parasites must be of an entirely different sort from those, because they must bear the most intimate relationship to the essential cancer cells. I feel that it is not impossible that an intracellular parasite plays a part here, but it cannot possibly play an independent part; it cannot possibly be the decisive element in the tumor; it cannot determine the nature and character of the tumor, for the cells alone do this.

I consider the existence of such parasites not impossible; — but what can be done to show their presence?

Experiments to demonstrate the inoculability of tumors from one individual to another show nothing in this regard. For this is nothing but the transplantation of tissue to another individual. Periosteum transplanted to another animal is able to grow in its new host and to form cartilage and bone; or to take a more familiar example, epidermis cells planted upon the surface of a wound of another individual may assume an extreme activity. Successful inoculation of tumors is in no way different. Here it is nothing else than the production of a secondary tumor, or metastasis in a second individual. Parasites are not required.

If we had only succeeded in producing tuberculosis by means of tuberculous tissue, the truth could never have been brought that tuberculosis was produced by tubercle bacilli. The parasitic nature of tuberculosis was only permanently and definitely established by the fact that by the inoculation of absolutely clean tubercle bacilli, free from all remains of tissue, the same result could be obtained as by tuberculous tissue, only by the fact that absolutely pure bacilli always produce primary tuberculosis in proper animals. We cannot show the etiologic nature of cancer or its power of transplantation by producing new secondary cancers even in another individual but only by producing primary tumors. Until that succeeds, and by pure, artificially grown organisms, the parasitic nature of cancer has not been proven.

Another question remains to be considered, viz., whether the present condition of our knowledge demands the assumption of a parasitic origin for cancer. Long before the parasites of infectious diseases were discovered, there could be no doubt that such must exist; and even to-day there are diseases, I need mention only syphilis, in which we do not know the parasitic cause, but cannot doubt that it must be present. Is the condition similar as regards cancer?

The fact which is to be explained in cancer is the limitless, the heterotopic growth of epithelial cells. I will not enter further into the question of how this may be explained than to state that there are many possible explanations and that the facts are not such that a satisfactory explanation can only be obtained by the assumption of a parasitic influence, but that we are quite able to explain all the phenomena in the morphology and histology of cancer without parasites.

I come thus to the following conclusions in regard to the question of the parasitic origin of cancer:

(1) No one has at the present day brought proof that cancer has a parasitic origin.

(2) There is no necessity of assuming a parasitic etiology for cancer.

DR. CARL PFISTER, of New York City, presented a paper containing a summary of the treatment of three hundred cases for hernia.

SECTION I—GYNECOLOGY

SECTION I — GYNECOLOGY

(*Hall* 13, *September* 24, 10 *a. m.*)

CHAIRMAN: PROFESSOR HOWARD A. KELLY, Johns Hopkins University.
SPEAKER: PROFESSOR JOHN CLARENCE WEBSTER, Rush Medical College, Chicago.
SECRETARY: DR. G. H. NOBLE, Atlanta, Ga.

SOME FUNDAMENTAL PROBLEMS IN OBSTETRICS AND GYNECOLOGY

BY JOHN CLARENCE WEBSTER

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MARKED as have been the advances during the modern scientific era in our knowledge of woman in respect to her anatomic and physiologic peculiarities, her special diseases, and the treatment thereof, many problems yet await solution, some of which are chiefly of scientific interest, others of therapeutic importance.

In complying with the request of the organizers of this great Congress, I have fully realized the seriousness of the responsibility which I have assumed in restricting myself to the topics which I have selected for your consideration. I have avoided all reference to matters pertaining to the treatment of disease, believing that the presentation of certain fundamental scientific problems would be more in keeping with the aims of this convention. I have also deemed it best to confine myself to a few topics of particular interest or importance, rather than to wander discursively over the entire scientific field open to the gynecologist. Your attention is, therefore, directed to the following subjects:

1. The determination of sex.
2. The structure of the ovary.
3. The functions of the ovary.

4. Antagonism between maternal organism and ovum.
5. Functions of the placenta.

Determination of Sex. From the time of Hippocrates to the beginning of the eighteenth century, about five hundred theories relative to the question of sex-determination had been advanced. During the last two hundred years this number has been considerably increased. At the beginning of the twentieth century, it must be frankly admitted that the problem of sex-determination in the higher vertebrates generally still remains to be solved. The most important observations and experiments bearing on the question have been made during the last fifty years, and from a study of these it would appear that the most exhaustive researches in comparative and experimental embryology and physiology will be necessary before the difficulties of the subject can be elucidated. The data furnished by the study of human beings are scanty and of little value. Most of the statements which have been made are speculative in nature, or of doubtful accuracy. Certain it is also that all attempts to regulate the production of sex in the human fetus in utero have met with failure.

In many countries the belief has long been current that the sex of the human fetus could be modified during a greater or less period of its uterine life. Now we know that the sex is fixed at least by the beginning of the second month, for at that time the microscope can distinguish ovarian from testicular structure. It is, therefore, scarcely credible that any reversal of sex can be brought about after this period by any conceivable combination of influences. We must, indeed, look to conditions existing during the first month of gestation, or at the time of the meeting of spermatozoön and ovum, or to influences affecting either or both of the latter before conception, in order to find explanation of sex-determination in the human embryo. Those who believe that both sperm and ovum share in the production of sex refer to the various statistics giving the relationship of the parental ages to the sex of the offspring. Hofacker in 1823, and Sadler in 1830, independently stated, as the result of an analysis of about 2000 births, that when the father is the older the offspring are preponderatingly male; while if the parents be of the same age, or if the mother be older, there is a larger percentage of female children. This generalization, termed the law of Hofacker and Sadler, has been the subject of much debate, having been upheld by some and denied by others during the last 70 years.

Those who believe that the influences determining sex belong to the ovum entirely find no evidence to support them from a study of the highest forms of life, though there is strong corroboration from investigations made among lower forms. Thus in cases of parthenogenesis it is evident that the influence of a male paternal element must be entirely eliminated in the determination of sex. B. S. Schultze advanced the view that there are two kinds of ovums, one of which may give rise to males, the other to females, but there has been no proof of such a differentiation in the higher forms of life. In several low organisms, however, it appears that these two varieties (of ovums) exist. Thus Korschelt describes two kinds of ovums in the ovaries of the worm *Dinophilus opatris;* one of large oval shape, developing into females, the other small and round, becoming males.

With regard to the determination of sex by influences brought to bear either upon parents, the sexual elements, or embryos, many observations have been made, but trustworthy conclusions may be derived only from the study of comparatively low organisms. The influence of nutrition is thus considered of great importance in determining sex. As illustrations may be noted the variations in the sex of frogs associated with changes in the nutriment supplied to the young tadpoles. Yung found that when the latter were left to themselves the percentage of females was slightly in the majority, but when very rich food was supplied, 92 females to 8 males in every hundred were produced. In the case of bees it seems evident that the influence which decides whether the offspring of the fertilized ovums shall become queens or workers is the nature of the food-supply. Rich and abundant diet develops queens; plain and scanty food leads to the production of workers, in whom reproductive organs are undeveloped. Very interesting observations have been made upon plant-lice or *aphides*. In the warm months when food is plenty they reproduce by parthenogenesis, the offspring being entirely female. When colder weather and scantier food appear there is sexual reproduction and an offspring of males. In the artificial life of a well-kept greenhouse, these phases may be repeated at the will of the observer, by varying the nutrition. So far as the temperature is concerned, Geddes and Thomson state that experiments point to the conclusion that favorable conditions tend to femaleness and extremes to maleness of offspring. As regards higher forms of life, it is impossible to estimate the importance of nutrition, temperature, etc., in the determination of sex, while as regards mammalians this field of inquiry is as yet entirely speculative.

From what is known of the early embryology of many invertebrates and some of the lower vertebrates, it would appear that their early embryonic life is one of indeterminate character so far as sex is concerned, during which various conditions, *e. g.*, nutriment, temperature, moisture, light, may act so as to produce maleness or femaleness according to their abundance or deficiency. Whereas, in the higher vertebrates, the period of embryonic sexual indeterminateness (if any) is very short, and so far as is known no influence can be brought to bear on the ovum which can in any way determine sex. The mammalian ovum developing in the uterus seems to enjoy such a sheltered existence that it is impossible to conceive that changes may be induced in its environment comparable to those which have been experimentally introduced in the study of ovums and embryos of low vertebrate and invertebrate forms of life. Indeed, it would seem that the most satisfactory theory of sex-determination in the higher vertebrates is that which supposes the existence of two forms of ovums — one destined to maleness and the other to femaleness, though it is impossible to establish any such differentiation by microscopic study or chemic analysis. The elaborate work of von Lenhossek, recently published, strongly favors this view that sex is fixed in the ovum before the spermatozoön fertilizes it. If such be the case it is quite futile to expect that any alteration may be brought about by dietetic or other influences made to affect the human female either before or during gestation.

In this connection it is interesting to refer to the question of the occurrence of true hermaphroditism in the human species. Many hold that this has never been demonstrated. Nagel, for example, states that it probably cannot exist, and holds that the ovary is never found with the testes in cases of so-called hermaphroditism. Recently, however, Sarré has described the case of an individual with the external configuration of a woman, who possessed a well-developed imperforate penis. On making a rectal examination, two small bodies, each the size of a pigeon's egg, could be felt in the left half of the pelvis, while in the right inguinal canal an ovoid body was found. An exploratory incision was made over the latter and the swelling removed, along with a smaller mass attached to it. Microscopic examination proved these to be testicular structure and epididymis. Another small mass near the testicle was also examined and found to be ovarian tissue. A Fallopian tube and a structure resembling the vas deferens were also present. Sarré believes that, with the exception of another case described by Ziegler, all other records of true human hermaphroditism are very doubtful, though he thinks it has been clearly demonstrated in some lower mammals, *e. g.*, the pig.

The Structure of the Ovary. In spite of the immense amount of investigation to which this organ has been subjected, many points in its development, normal and pathologic histology, still require elucidation. It is generally agreed that the ovary is developed from epiblast and mesoblast on the inner surface of the Wolffian body. The epiblast, a specialized portion of the celomic lining, very early forms a mass consisting of several layers of cells, the germinal epithelium. In the deepest portions certain of these cells increase in size, giving rise to the primordial ovums. The latter are all formed previous to birth. As the epiblast layer increases in thickness, processes of the underlying mesoblast of the Wolffian body extend outward among the germinal cells, forming a network-like stroma, in the meshes of which lie primordial ovums, frequently surrounded by germ cells. Regarding the formation of the primary follicle, there are differences of opinion. Most believe that the germ cells arrange themselves around the ovum forming the primary ollicle, in later life proliferating to form the membrana granulosa. In 1878, Foulis, of Edinburgh, contended that the cells surrounding the primordial ovums are derived from connective tissue, and lately Wendeler and Clark have advocated this view. The latter has pointed out that the cells are usually spindle-shaped in the early stages and that frequently primordial ovums are found without any special layer of cells surrounding them. Kölliker stated that the follicular epithelium was derived from Wolffian epithelium, but this view has received little support. Regarding the changes between birth and puberty, we do not possess exact information. It is believed that during this period more than half the primary follicles disappear, though the manner and reason of the disappearance are not clear. The period of puberty is characterized by the development of Graafian follicles, which rupture gives rise to the peculiar structure of the corpus luteum. In some cases this phenomenon may be noted months before the external signs of puberty are detected and occasionally years previously. The explanation of these variations is not known. Some degree of development of the ovum seems to be a normal occurrence in the pre-puberty period. Stevens has recently described these as follows: The follicle and contained ovum mature to a certain extent. The single layer of flat cells surrounding the dormant ovum proliferates and becomes somewhat cubical, several layers being formed — membrana granulosa. The ovum increases and is surrounded by a discus proligerus; there is also a zona radiata and liquor folliculi. At its greatest the follicle measures about .8 × .7 mm.; the ovum, .1 × .095 mm. The tunica fibrosa is well marked, and resembles the ovarian stroma, being somewhat more vascular. Sometimes excessive liquor folliculi collects. Retrograde changes gradually develop. The ovum is invaded by cells, which are apparently phagocytes, derived probably from the membrana granulosa. Their protoplasm is vacuolated and they do not resemble leukocytes. Necrobiosis gradually develops, and most granulosa cells disintegrate. The tunica fibrosa gets many capillaries and the connective-tissue cells multiply. On the inner surface a hyaline layer of fibrin forms, in which new connective tissue develops. The follicle gradually shrinks, leaving a small scar area. It thus appears that the pre-puberty changes in the follicles differ from those in adult life in the following particulars: the ovum does not reach such a large size. The wall of the follicle external to the membrana granulosa does not present a two-layer arrangement; there is no rupture of the follicle; there is no formation of a corpus luteum; the ovum is invaded by phagocytic cells. In adult life, also, it is to be noted that, beside the follicles which rupture, there are others which may develop to a certain extent and then undergo retrograde changes before rupture occurs. The ovum may increase, a yellow body may form, owing to the development of lutein cells in the theca interna. Then the ovum and surrounding epithelium degenerate and are absorbed, along with the liquor folliculi. The explanation of such a process is not always certain. In some cases it appears to be due to chronic inflammatory changes in the ovary, but it is probably also due to other causes of which we are ignorant.

Regarding the bursting of the follicle there is a difference of opinion. Most authorities hold that the ovarian tissue, being greatly thinned at the most projecting point, is gradually ruptured by the increase in intrafollicular pressure resulting from the accumulation of liquor folliculi. Nagel, however, holds that owing to an increase in the thickness of the inner layer of theca folliculi, to the swelling of its cells with lutein particles and to its becoming arranged in a wavy manner, pressure is made on the follicle contents from without, and that they are forced in the direction of least resistance, viz., outward toward the surface of the ovary.

Clark holds that rupture is due to changes in the circulatory conditions in the ovary. Owing to the marked engorgement of the organ, tension is increased and the follicular contents are forced to the surface. The vessels lying external to the folicle at the bulging portion are compressed, and consequently necrosis and disintegration of the tissue take place. *Pari passu* with the development of the lutein cells there is fatty degeneration in the cells of the stratum granulosum and in those of the discus proligerus. This enables the ovum to escape easily from the cells surrounding it.

The formation of the corpus luteum has given rise to considerable discussion. Some workers still hold firmly that it is a derivative of the membrana granulosa. The majority hold, however, that it is developed from the inner part of theca folliculi, which is regarded as a cellular layer of the connective-tissue stroma of the ovary.

Of great interest is the observation recently made by Stoeckel, Pick, and others, that, occasionally, corpus luteum cells may not undergo their normal growth and retrogression within the limits of the follicle, but may wander outward into the ovarian stroma and even undergo atypic proliferation. I have occasionally noted this wandering, though not to a great distance; in some instances the cells contained abundant dark pigment apparently derived from blood which had been effused into the cavity of the follicle. The explanation of these irregular phenomena is quite uncertain, and is deserving of careful investigation.

Another interesting histologic appearance has been described in recent years by Pels Leusden, Schmorl, and others, viz., small localized areas of decidua-like cells in the ovary in some cases of uterine pregnancy. I have recently examined ten specimens in my museum, and have found these changes in four ovaries. In one a single area was found in a complete section of the ovary; in the others, two were found at different portions and varying in size. In each instance the areas were situated in the cortex, at or near the surface, sometimes projecting slightly from the latter, sometimes extending some distance into the cortex. The cells in these areas bear the closest resemblance to the uterine decidua in normal pregnancy, presenting similar variations in size and shape. The line of demarkation from the surrounding ovarian stroma is always well marked, giving the impression that the two tissues are distinct. Usually these areas contain dilated capillaries which are not found in the neighboring unchanged ovarian stroma.

I have never found such areas in ovaries removed from non-pregnant women. What is the explanation of these changes? It might be suggested that they are peripheral portions of the theca interna of the ripening Graafian follicles or of a corpus luteum. Serial sections show, however, that this is not the case. The large cells are undoubtedly of connective-tissue origin, but their definite localization suggests some special characteristic which makes the cell capable of undergoing the same genetic reaction which is ordinarily found in the uterine and tubal mucous membrane when pregnancy develops in relation to these tissues.

Tentatively, I advance the view that these areas represent displaced portions of Müllerian tissue, which have become attached to the surface of the ovary in early embryonic life. Occasionally, I have found in the substance of such an area a gland-like space lined with columnar or cubical epithelium. The latter may, of course, be simply a derivative of the surface germinal epithelium, but it may indeed represent included Müllerian epithelium.

It is possible that the special genetic reaction in these areas may sometimes determine the imbedding and development of a fertilized ovum in the ovary, and if the opinion that they are Müllerian in origin be correct, it is not unlikely that all cases of pregnancy in ovarian tissue may still serve to support the dictum which has been widely believed in recent years, viz., that imbedding and development of the fertilized human ovum in the earliest stages can only take place in a tissue capable of undergoing a special genetic reaction, and that this tissue is in all cases Müllerian in origin.

While the proof of this is impossible, all *a priori* evidence is in its favor. Those who attempt to overthrow the hypothesis certainly undertake a heavy task in trying to establish an exception to the uniformity of performance of one of the most complex and highly specialized functions in the human body. The indication of the genetic reaction is decidual transformation, and this is normally found only in the mucosa of the corpus uteri, where indeed it occurs in all cases of pregnancy, whether the latter be uterine or ectopic. In certain cases we know that decidual changes may occur in other portions of the Müllerian tract, most frequently in the Fallopian tubes, a fact which probably helps to explain the occasional occurrence of pregnancy in the latter.

With regard to ovarian gestation, in the specimens which have been most fully studied, viz., those of von Tussenbroek, Thompson, and myself, it is true that no definite decidual layer is found in the wall of the gestation sac. Though von Tussenbroek, in her first description, mentioned a decidual layer, she afterward stated that this was an error, the cells being in reality lutein cells of the corpus luteum. The final account is in the main correct, but she cannot deny the possibility that some of the large cells were decidual. However, admitting that no decidual cells are found in specimens as advanced as those mentioned, we do not know that they were not present at an earlier stage, when the ovum was very small. One of the small ovarian decidual areas to which I have referred would very soon disappear as a result of the outward pressure of the expanding ovum, as well as of the phagocytic action of the trophoblast, if there be no more tissue capable of undergoing decidual changes, and it is quite evident that the ovarian stroma proper does not tend to undergo this transformation.

Even in tubal pregnancy, in which decidual changes are always present in the early stages, there may be a marked disappearance as pregnancy advances, the production of cells being evidently much poorer than in the uterine mucosa in normal pregnancy, though in the latter there is a considerable range of variation. In my own recently described specimen of ovarian gestation I believe that I have demonstrated a few scattered groups of decidual cells in the ovarian stroma, near the inner wall of the gestation sac.

For several years I have held the belief that decidual transformation is peculiar to the Müllerian tract. The occasional finding of the small areas of decidua-like cells in the ovary in uterine gestation has been regarded by several writers as a proof that other tissues may also undergo the change. From what I have already stated it remains to be proved that these areas are not Müllerian in origin. The occasional blending of Müllerian and ovarian tissues has been abundantly proved, both by macroscopic and microscopic demonstration. Take, for instance, the relationships of the ovarian fimbria. In some cases its outer end may not reach the ovary, sometimes it may just touch it; sometimes its tip may be imbedded in the ovary; sometimes a considerable extent of the fimbria may lie against the ovary or adherent to it; in some cases there may be a break in its continuity, so that a small outer portion may lie close to the ovary detached from the main part. Marchand has directed attention to the early close relationship between the tubal epithelium and that covering the surface of the ovary, and has pointed out that they are one and the same surface. He believed that in some cases the line of demarkation, instead of being at the end of the ovarian fimbria, might reach over to the lateral portion of the ovary and that from it processes might extend into the cortex of the ovary. The observations of De Sinety and Melassez, in 1878, seemed to establish the correctness of such a view. Other studies, especially those of Whitridge Williams, leave no doubt as to the occasional extension of Müllerian tissue into the ovary. It need not, therefore, be a matter of surprise that small areas are occasionally found in the ovary of pregnancy, presenting the appearance of decidual changes in the connective tissue of the uterine mucosa.

It must also be mentioned that small localized decidual nodes have also been found in the broad ligaments. I believe that these are also derived from displaced portions of Müllerian tissue, which are quite common, especially in the upper portions of the broad ligaments. Similar areas have also been found under the peritoneum of the pregnant uterus, but this cannot be considered as at all remarkable, since there is no doubt as to the Müllerian nature of the uterus. Rarely they have also been found behind the peritoneum of the pouch of Douglas, and it is not unlikely that even in this neighborhood may be found small detached Müllerian fragments displaced backward in early embryonic life.

In describing these small decidua-like areas it must be remembered that somewhat similar appearances may sometimes result from chronic inflammatory changes in the peritoneum, associated with inclusion of the endothelium and proliferation of the latter. The large cells produced in this manner are usually closely packed and suggest masses of epithelium rather than the looser arrangement of multiform anastomosing cells found in the connective-tissue decidual areas.

The Functions of the Ovary. In addition to furnishing the ovums, it has long been recognized that the ovary exercises an important influence on the body, though the nature of the influence and the changes induced by it have been and still are unknown. Recently, various workers have suggested that the ovaries are ductless glands, whose internal secretion affects general metabolic processes.

Several years ago, it was noted that in many cases of osteomalacia the disease could be checked by removal of the ovaries. Fehling, a pioneer in this line of work, made a careful study of the urine in his cases, but gained no information as to metabolic changes by comparing its condition before and after operation.

In 1894 and 1896, Neumann stated that removal of the ovaries in this disease exercised a marked effect in lessening the excretion of magnesium, calcium, and phosphorus, as well as diminishing proteid disintegration. Later, Neumann and Vas experimented on normal female animals, and found that Merck's ovarian tabloids, even in large doses, did not appreciably alter the quantity of nitrogen or phosphorus in the urine. They found, however, that there was an increased excretion of these when their own preparation of cow's ovary was administered. They also noticed no pronounced alteration in the phosphorus excretion after removal of ovaries from animals. When ovarian tabloids were given to spayed animals, there was increased excretion of calcium and phosphorus, and less marked nitrogenous excretion.

The experiments of Curatulo and Tarulli, in 1895, have attracted a good deal of notice. They fed bitches on a regular diet until there was a uniform average daily excretion of phosphorus and nitrogen. The ovaries were then removed, and thereafter the excretion of phosphorus was much diminished. They concluded that the ovaries produced an internal secretion, of unknown nature, which influenced the oxidation of organic substances containing phosphorus which enter into the structure of bone. In accordance with their view, it has been widely believed that the beneficial influence of the removal of the ovaries in osteomalacia was due to the retention of more phosphorus in the system and its deposition in the bones in the shape of phosphates.

In 1899, Falk repeated these experiments, but did not arrive at the same conclusions. After removal of the ovaries in two bitches, he noticed no difference in the amount of phosphorus excretion.

Moreover, recent investigations regarding the source of the excreted phosphorus tend to lessen the value of these experiments. They appear to show that much of the phosphorus is derived from nucleoproteid in food, and it is possible that the increased excretion after the administration of ovarian tissue or extract is thus explained. Curatulo also holds that the ovarian secretion favors the oxidation of carbohydrates and of fatty substances, and explains the tendency to corpulency when the ovaries are removed in the reproductive period of life, or after the menopause, as due to the loss of the ovarian secretion.

The results of various experiments in the administration of ovarian tissue or extract in the human female have in no way helped to throw light on the subject under consideration, nor have they tended to uphold the theory of an internal secretion. The use of the gland in various diseased conditions of the pelvis has not served to give to it any definite therapeutic value. Neither has its administration at the time of the climacteric served to ameliorate or dispel the troubles incident to that period. Results, good, bad, and indifferent, have been published, leading strongly to the conclusion that in the cases observed only the same variations in clinical features have been recorded which may be recognized when any group of menopause cases is studied uninfluenced by any medication.

Whatever the influence of the ovaries may be, it seems to be established that they affect the organism through the circulation and not through the nervous system, and thus support is given to the theory of an internal secretion. Many experiments have been made in transplanting the ovaries of animals from their normal situation to some other, *e. g.*, the peritoneum, subcutaneous tissue, muscles, etc. While after transplantation some of the ovarian tissue usually necroses, the remainder generally lives and continues to functionate, ovums continuing to develop, ripen, and even to escape from follicles. When this activity continues, no matter where the ovary is placed, the genitalia and mammae remain well developed just as though the organ is in its normal position.

The Rôle of the Corpus Luteum. Recently the view has been advanced that the internal secretion of the ovary is produced by the corpus luteum, and that the latter structure exercises very important functions in the female organism. The late Gustav Born, of Breslau, was the first to bring forward this hypothesis, stating that the particular function of the corpus luteum was to favor the imbedding and development of the fertilized ovum in the uterine mucosa.

Ludwig Fraenkel has recently published an elaborate paper in which he states his belief that the internal secretion produced by the yellow body keeps up the nutrition of the uterus during reproductive life, leads to the phenomena of menstruation, and favors the imbedding and development of the fertilized ovum. Uterine atrophy and amenorrhea are brought about when no corpora lutea are found. Thus are explained the conditions normally found before puberty and after the climacteric. The facts upon which this remarkable hypothesis is based are derived mainly from experiments carried out on rabbits, since in these animals the time of occurrence of the various stages of gestation, following insemination, are fairly accurately known.

In endeavoring to determine the influence of the ovary on implantation of the fertilized ovum, Fraenkel removed the ovaries from thirteen rabbits, one to six days after copulation. Later these animals were killed, and in no instance was an ovum found in the uterus. In another series only one ovary was removed, and this did not interfere with gestation. It seemed, therefore, that implantation had been prevented by removal of both ovaries.

In another series of rabbits the ovaries were removed after implantation of the ovums, and it was found that their development ceased, though they were not expelled from the uterus.

Similar results were obtained when, instead of removing the entire ovarian tissue, the corpora lutea were destroyed with a cautery. It was found that development of the ovum might continue if only one corpus luteum was left in the ovary. When the ovaries were transplanted, destruction of the ovum occurred, though after some delay. After burning the corpora lutea from the ovaries, it was found that the uterus was much atrophied in two weeks.

This physiologic interpretation of the function of the corpus luteum is worthy of the highest consideration. Hitherto, anatomic explanations have been chiefly prevalent. Thus, it has been considered as forming an extra protective covering to the ripening ovum, as a plug to check hemorrhage after bursting of the follicle, and as a kind of splint steadying the tissues during the process of healing. Clark has pointed out that it is evidently associated with a method of repair, which leads to little formation of connective tissue, and has well stated that if the ruptured follicles were healed by the ordinary method, the ovary would be converted into a mass of connective tissue, which would render the escape of ovums increasingly difficult.

On the other hand, Fraenkel and others who adopt the physiologic interpretation, emphasize the well-known structural resemblance of the fully-formed corpus luteum to a ductless gland, since it consists of rows of large epithelioid cells — the lutein cells, arranged somewhat radially, strands of delicate connective tissue containing blood-vessels ramifying between the columns. Fraenkel holds with Sobotta and others that the yellow body is derived from the membrana granulosa, and that thus an epithelial origin is obtained for the cells of the glandular organ. I have already pointed out that many authorities hold that the corpus luteum is derived not from the membrana granulosa, but from the connective tissue external to the latter, while a considerable number hold that the membrana granulosa is itself of connective-tissue origin. If the latter view be correct, and the glandular nature of the corpus luteum be established, such a marvelous transformation of connective tissue is without parallel in any other portion of the human body. But even if its origin be epithelial, it is equally remarkable and unique that a glandular function should be carried on during many years by a continued series of new formations in different portions of an organ.

In considering Fraenkel's hypothesis, various questions suggest themselves for investigation. If the corpus luteum causes the phenomena of menstruation, why is the latter function limited to the primates? Born has pointed out that in all animals in which there is a uterine insertion of the ovum there is a well-developed corpus luteum, whereas in all other animals the latter is either rudimentary or not developed at all. In all mammalians above the monotremes the ovum is implanted in the uterus and the corpus luteum is well developed. The absence of menstruation in the great majority of these must either be due to some peculiarity of the corpus luteum or to other unknown reasons.

If the corpus luteum presides over the implantation of the ovum through its internal secretion, does the latter influence the ovum by passing to it through the maternal tissues (where presumably it circulates) or is the ovum already influenced at the time it escapes from the follicle? Fraenkel's experiments seem tô negative the latter hypothesis, for if the ovum reaches the uterus already charged with the secretion, destruction of the corpora lutea in the rabbit might not be expected to affect its implantation. It is therefore more reasonable to suppose that contact with the uterine mucosa in which the ovarian secretion circulates leads to the conditions which determine the imbedding of the ovum. From histologic studies it is now known that the implantation of the ovum in the mammalia occurs after certain changes have taken place in it, that in the vesicular stage there is a proliferation of the outer layer of epiblast forming the trophoblast which has the power of attaching itself to the uterine mucosa, of absorbing the latter and burrowing into it. Is this power dependent upon the influence of a circulating ovarian secretion? Hitherto it has always been believed that these changes were possessed by the ovum itself, for in animals developed from ovums which find no resting-place in the body the development of the ovum does not depend upon the maternal organism.

It must, however, be believed that in the higher mammals, at least, some special complementary characteristic must be found in those areas of maternal tissue on which the ovum grows. In the human female, for example, as I have already pointed out, a particular portion of the Müllerian tract, viz., the mucosa of the corpus uteri, is the normal seat of implantation. The normal occurrence of a decidual reaction in this area has already been noted. Is it possible that this peculiar change is brought about by the ovarian secretion and is a prominent indication that the tissues are favorable to the reception of the ovum?

Recently various authors have suggested a connection between abnormal conditions of the ovary or corpus luteum and aberrant developments of the ovum. Thus several cases have been described in which hydatidiform mole has been associated with disease in the ovary, especially cystic degeneration. Pick has recently made a careful study of a case in which excessive production of lutein tissue was found in the ovaries, and he regarded this condition as the cause of excessive chorionic development, leading to the formation of hydatidiform mole. In chorioepithelioma this author, Runge, and Jaffé have also described excessive production of lutein cells in the ovary, which they are inclined to consider as the cause of the chorionic growth. In several specimens of ovaries examined by Pick, Stoeckel, Runge, and others, in addition to cystic changes in Graafian follicles and corpora lutea, collections of lutein cells were found scattered through the ovarian stroma. Careful study of a larger series of ovaries must be made before any positive statement can be made in regard to the association of changes in them with abnormal development of the ovum. It is certainly difficult to explain the occurrence of hydatidiform mole in a twin pregnancy by the lutein secretion hypothesis. If over-production of the latter be the sole cause, it is strange that both ovums should not be similarly affected.

The Antagonism between Maternal Organism and Ovum. For several years the idea has been steadily gaining ground that the maternal organism during pregnancy is very commonly affected by circulating toxic substances, and that many disturbances, both of major and minor importance, are caused thereby. This view has been chiefly prominent in recent investigations concerning the nature of eclampsia. Though little success has been obtained in the identification of specific toxins, there has been plenty of speculation as to their source and nature. The maternal organism has been considered the chief source of their production, the contribution of the ovum being generally regarded as of minor importance.

Recently, however, a new theory attributes to the latter a much more prominent rôle than has hitherto been suspected. In addition to the passage into the maternal circulation of the waste products of fetal metabolism, it is believed that there is a continual warfare between the chorionic layers of the ovum and the maternal tissues, that the proliferating and invading tendencies of the former are continually antagonized by the latter, and that a toxic chorionic internal secretion is produced which is neutralized or destroyed by maternal influences.

In normal cases of pregnancy it is considered that there is established a kind of equilibrium between the ovum and maternal organism; that in some abnormal cases the ovum suffers as the result of predominant activity of the maternal elements, while in others the maternal organism suffers when the ovum is in the ascendant. In the former instance the ovum may be destroyed and abortion result; in the latter the mother may exhibit phenomena of various kinds, from the minor nervous and alimentary disturbances of pregnancy to such marked disorders as pernicious vomiting or eclampsia. This same theory would also explain the rapid growth of chorionic tissue after pregnancy, giving rise to chorio-epithelioma malignum, as mainly due to some defect in the maternal factors which normally counteract the excessive proliferation of chorionic epithelium.

These newer lines of thought have followed close upon the establishment, by recent workers, of the exact histologic relationships between the human ovum and uterus. It has been demonstrated beyond doubt that the early ovum in its vesicular stage is characterized by a proliferation of its outer epiblastic covering forming a layer of cells, distinct from one another, known as the trophoblast, and that through the activity of this layer the ovum burrows into the superficial part of the uterine mucosa, where it becomes completely imbedded. The trophoblast continues to extend outward in all directions, lacunas appearing in it. Into the latter, blood finds its way from maternal sinuses which have been opened by the phagocytic activity of the trophoblast. The entire trophoblast is in this way converted into a sponge-like structure. The lacunas enlarge, and the trabeculas between them become smaller. The former are the forerunners of the permanent intervillous spaces of the placenta, the latter of the villi. The trophoblastic cellular trabeculas are gradually penetrated by the mesoblastic layer of the chorion in which the terminal branches of the umbilical vessels carry on the fetal circulation. As soon as lacunas appear in the trophoblast a change takes place in the cells of the latter lining the lacunas. They appear to become fused into a continuous layer of nucleated protoplasm in which no cell outlines can be distinguished. This is the earliest stage in the formation of syncytium, and was regarded by Peters, in whose specimen it was demonstrated, as caused partly by the pressure of the maternal blood in the lacunas, partly by the influence of the blood-plasma; in some parts, also, blood-corpuscles appeared to become degenerated and to fuse with the trophoblastic cells.

As pregnancy advances, the syncytium rapidly increases so that it covers the entire chorion. The unaltered trophoblast cells subjacent to the syncytium form the layer universally known as Langhans' layer. Wherever the chorion comes into contact with the maternal decidua, evidence of invasion of the latter by the former is found, but it is chiefly noticeable at the site of the placental portion of the chorion, the decidua serotina. Here in the early weeks of gestation irregular extensions of syncytium may be found. They are chiefly noticed in the compact layer of the serotina, but are observed in the spongy layer, and even in the muscular wall. Portions undoubtedly extend into maternal blood sinuses, to whose walls they may become attached. Small portions of syncytium also may be carried away in the venous circulation. That this may take place throughout a considerable period of pregnancy is highly probable. Several authors hold that pieces of villi, comprising both epithelial and connective-tissue elements, may also be deported, though I have never observed this in normal specimens. Whatever be the extent of the process no important anatomic lesions in the vessels of the lungs or elsewhere have been demonstrated to result from them. The chorionic fragments are very small and are probably rapidly disintegrated in the maternal blood. Their destruction is explained according to Ehrlich's now well-known hypothesis. The foreign fragments produce a substance which fixes them to the red blood cells, and which also enters the serum, forming an antitoxin, which tends to destroy the fragments. Veit has termed the latter syncytiolysin. Various experiments have been made in support of the view that the chorion produces a toxin which may cause various morbid changes during pregnancy unless continually destroyed by the maternal organism. Thus Politi injected sterile filtered extract of human placenta into rabbits, producing death in some cases with spasms and marked prostration. He states that the toxicity of the extract was lowest when the placentas of healthy women were used and most marked in the case of eclamptics. Ascoli has also made interesting experiments, in which placental infections produced some of the phenomena of eclampsia. Beside the influence of the blood in counteracting the syncytiotoxin, it is believed by some that the decidual cells also share in this function. Bandler holds, in addition, that the ovary also furnishes an element in its secretion which is antagonistic.

Functions of the Placenta. It has been clearly established that the placenta is entirely an organ of the chorion, consisting of projections of the latter termed villi, which are attached to the uterine mucosa, and bathed by maternal blood circulating among them.

Comparatively little is known as to the nature of the interchange of materials between the fetal and maternal circulations through the medium of the villi. For many years the placenta has been regarded merely as the medium through which nutritive material and oxygen passed from the mother to the fetus, and the effete products of fetal metabolism from fetus to mother; it was considered to be a kind of fine sieve, through which percolation took place, or a diffusion membrane that favored osmosis. It is now almost certain that the transmission of substances between the maternal and fetal blood is not merely a matter of physics. The chorionic epithelium is believed by many to be a highly differentiated tissue, capable of carrying on complex vital processes, possessing powers of selection, elaboration, and even digestion. Marchand has suggested that the syncytium is the chief factor in the absorption of nutritive material from the maternal blood, the Langhans layer being more concerned with the transmission of waste products from ovum to maternal blood. Cavazzani and Levi state that there is no correspondence between the quantity of urea in the maternal and fetal blood, that there is more glucose in the former than in the latter, and that the density of the fetal blood is greater than that of the maternal blood. It appears that there are considerable variations in the transmission of substances through the placenta at different periods of pregnancy. Thus, in the last three months, there is a great increase in the iron, potash, and lime stored up in the fetus. In the early months there is a great predominance of soda over potash.

Various materials may be stored in the placenta. Thus, it undoubtedly fixes glycogen. It is thought that albuminoid material is transmitted as soluble peptones, though this is not definitely known. There has been some question as to the possibility of the passage of maternal leukocytes through the walls of the villi entering the fetal circulation. Varaldo states that there are more leukocytes in the umbilical vein than in the umbilical arteries, there being, on the average, considerably more per cm. in the former than in the latter, and that more of them contain iodophilic granules in the former than in the latter. It has, therefore, been concluded by several that leukocytes normally carry substances (possibly nutriment) to the fetal tissues. This has not been proved, however. In maternal leukocythemia there is no corresponding increase in white corpuscles in the fetal blood.

The placenta acts as a protective barrier against the invasion of the fetus by various poisons. It is more efficacious against some than against others. Porak's experiments on the guinea-pig, for example, show that in this animal copper passes easily, arsenic with difficulty, and mercury, not at all, the poisons being stored to a greater or less extent in the placental tissue. With regard to microörganisms and their toxins, little is known. Many microbes are able to pass from mother to fetus, but nothing is known as to the conditions associated with the transit. It does not appear that any placental lesion is necessary. The placenta appears to be more resistant to some organisms than to others. Thus it is clearly established that tubercle bacilli rarely pass through it; indeed, cases of Lehmann and others prove that though tuberculosis may begin in the placental tissue, the fetus may not be affected. In this connection, however, it must be noted that sometimes tubercle bacilli may be present in the fetus, though no lesions be present, since inoculations of guinea-pigs with portions of the fetal tissues may cause tuberculosis.

It seems certain that in the great majority of cases the placenta is the sole route by which microörganisms and toxins reach the fetus. It is possible that they may pass through the amnion into the amniotic fluid and thence enter the fetus, but this is probably a very rare mode of injection. Charrin and Duclert's experiments on guinea-pigs suggest that the passage of germs through the placenta is helped or retarded by varying conditions of the maternal blood. Thus they found retardation when the maternal system was saturated with corrosive sublimate. When tuberculin, alcohol, lead acetate, or lactic acid were present, the passage of the germs seemed to be facilitated. Neelow has experimented on pregnant rabbits, and states that nonpathogenic organisms cannot pass from mother to fetus.

The placenta suffices to allow the fetus to grow and thrive in many diseased conditions or malformations incompatible with health or life in the adult. Pathologic conditions affecting the structure and function of the placenta endanger the life of the fetus. In many maternal diseases, doubtless, the fetus is destroyed as the result of changes in the placenta, affecting its structure or function, produced by its resistance to the toxic material in circulation.

The placenta also acts as the great excretory organ for the fetus. Savory long ago produced tetanus in a pregnant cat by injecting strychnine into the fetus in utero. The passage of other drugs has been similarly demonstrated by others. Charrin holds that toxins placed in the fetus, either directly or by the spermatozoa of the father, may pass to the mother. This might explain certain cases of immunization in syphilis (Colles' law). By injecting diphtheria toxin into the fetus in utero he has killed the mother animal. Guinard and Hochwelker have shown experimentally that the passage of drugs from the fetus to the mother is stopped if the former is killed, and that if the fetus be injected after its death the drug is only found in its tissues. Baron and Castaigne have found that drugs introduced into the amniotic fluid are also transmitted to the maternal tissues, though much less rapidly than when injected into the fetus. If the latter be dead, the substances do not pass to the maternal circulation.

I have already referred to the theory that the chorionic epithelium produces an internal secretion, which may exercise a deleterious influence on the maternal system. Some hold that it may also act as a destroyer of certain elements circulating in the maternal blood which might be toxic to the fetus if it should enter the circulation of the latter.

SHORT PAPER

Dr. John A. Sampson, of Albany, N. Y., contributed a paper to this Section on, "The Importance of an Early Diagnosis in Cancer of the Uterus."

SECTION J — OPHTHALMOLOGY

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(*Hall 7, September 24, 10 a. m.*)

CHAIRMAN: DR. GEORGE C. HARLAN, Philadelphia, Pa.
SPEAKERS: DR. EDWARD JACKSON, Denver, Col.
DR. GEORGE M. GOULD, Philadelphia, Pa.
SECRETARY: DR. WM. M. SWEET, Jefferson Medical College, Philadelphia, Pa.

THE RELATIONS OF OPHTHALMOLOGY TO OTHER DEPARTMENTS OF SCIENCE

BY EDWARD JACKSON

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THAT ophthalmology has been given a place in this Congress of Arts and Science may be significant of its wonderful development in the last half-century. But it is still more significant of the new conception of what constitutes a science. There was a conception of sciences that we might compare with the representation of states in a primary geography. Each had a distinct color — pink for Missouri, yellow for Illinois, green for Kansas, with strong black lines separating them. If the color of one passed the black line and smeared the other, it was a grave blemish on the map. Receiving first geographic impressions from such a map, it becomes hard for the child to conceive that these arbitrary political divisions correspond to nothing in external nature. Lines equally distinct, equally arbitrary, equally unnatural, marked off from each other the different conventional divisions of science. To a generation trained in the older conception of separated sciences, astronomy, chemistry, botany, physiology, the failure to recognize the traditional boundaries may seem a loose disregard of valuable landmarks.

But in thought, as in geography, across all conventional lines the streams run, the winds blow, the landscape extends toward the infinite, alluring horizon. Each individual student, from the little hill or the mountain he has climbed, looks out upon a panorama of facts the exact counterpart of which no one else can view. Yet he beholds the same region that others see from somewhat different standpoints; and the breadth of his perception is determined not by busy running to and fro, rather by the height to which he has climbed in his own proper domain for a viewpoint.

The new conception of science recognizes its universal continuity; and laying aside traditional boundaries, assigns to every definite, important human interest, dominion over the territory which lies nearest it. Such is the conception which recognizes a science of ophthalmology.

Ophthalmology centres in the function of vision; a gateway — perhaps the most important gateway — between the objective and the subjective. From this centre of its domain, highways and bypaths go out in all directions, each leading to other domains of science, nearer or more remote. They run for a time fairly in the domain of ophthalmology, they end fairly at the centre of some other science; but where they cross the border lying between, no man shall say. The time devoted to this address is to be used in pointing out a few of the salient features noticeable from this particular centre of knowledge; in tracing the direction toward which the paths that centre here extend, and in indicating a few things of especial value that we are able to offer from our cultivation of the field of ophthalmology, or hope to import from other fields of activity.

The central fact of ophthalmology is the conversion of the light impulse into the nerve impulse, and this not in a single general act but by a myriad of sharply differentiated actions. We receive through the eye not merely a uniform impression of general external luminosity. Through this gateway comes a message from each separate particle of the universe. The number of such messages perceptible is limited only by a most remarkable capacity for differentiating impressions. A thirty-thousandth of a square millimeter of retina is capable of isolating and preserving the identity of a particular sensation, and of appreciating a radically different sensation ten times in each second.

This ability of the retina to differentiate impressions is of value only when connected with a correspondingly minute accuracy in the assorting of the rays falling upon it; and this minute accuracy in the assortment of these rays depends on the perfection of the dioptric apparatus of the eye. Its capacity for successive impressions depends on the rapidity of renewal of physical and chemic conditions — upon the perfection of its nutrition. To supply and maintain by most delicate adjustments and compensations, these two things, the dioptric assortment of rays and the nutritive conditions of vision, are the essential purposes of the eyeball and its appendages.

On the one side ophthalmology extends to include the whole science of optics. Optical instruments are but artificial extensions of the organ of vision, conditioned by its limitations, of value as they serve it. On the other side few processes of human physiology are without important bearing on ocular nutrition; and more distant processes, biologic, chemic, and physical, throw light upon the problems of ocular nutrition. On the one hand we have the mathematic and physical phenomena of light; on the other the physiologic balance of health and the imbalance of disease.

Ophthalmology was developed from both sides. The physicist and the optician with lenses and more elaborate instruments endeavored to correct the imperfections and extend the usefulness of the dioptric apparatus. The physician traced and combated in the eye morbid processes similar to those that he dealt with in other organs of the body. There is still a reactionary tendency to split the field of ophthalmology along the old lines. From the side of the optician the desire for maximum immediate material results with a minimum of science; and from the side of the physician the unwillingness to overstep the traditional boundaries of a medical education, and train the ophthalmologist in mathematic and physical optics, still favor one-sided and partial studies and views of ophthalmology. The real unity of science, and the importance of the sense of vision in the life of our modern civilization will, in the end, compel a view of the whole field from the true standpoint. But the opposing influences of a hasty commercialism, and a blind if not fossilized conservatism, must be met by the assertion and reassertion, clear and emphatic, of the unity of ophthalmology.

Physics and Mathematics. The two halves of the ophthalmic domain have been alluded to. Let us go into the relations of each of them a little more in detail before turning to special lines of thought that lead out toward the other domains of science. On the physical side of ophthalmology the general laws of refraction and the properties of lenses have been worked out nearly to the practical limit of minuteness. The exact changes in the dioptric mediums and surfaces of the eye, which occur with age, and in the act of accommodation, are still uncertain. This point at which physics and physiology come together is one of especial interest. More minute studies of both the physical conditions present in the crystalline lens and the physiologic processes which change them may yield suggestions of wide applicability both in general physiology and in general physics.

That part of the physical side of ophthalmology concerned with the movements of the eyeball, which secure and maintain binocular vision, has of late years attracted much attention. A voluminous literature regarding it has arisen, the bulk of which, to speak frankly, is worth very little. This literature exhibits with painful emphasis the general lack of a broad training among physicians which leaves them unable to grasp and use to advantage essential physical and mathematic conceptions. The same defective training is also seen in the crudeness and inefficiency of physical methods that have been widely resorted to for the correction of imperfect physiologic adjustments. The unknown being always great, the surgeon, painfully aware of the limitations of his knowledge of physiology, seems to have placed a blind faith in mechanical readjustments, of the limitations of which he was still more ignorant.

Fortunately, the importance of physiologic development for the perfecting of the function of binocular vision has been recently emphasized. Binocular vision is, comparatively, a late acquirement in the evolution of the race. The capacity for it is still rather liable to imperfect transmission from generation to generation. The instinctive reactions and efforts of the child in this direction often need to be guided, assisted, and supplemented. A better appreciation of this evolutionary process and its recapitulation in the individual becomes the antidote for blind dependence on crude mechanical remedies.

Physiology. Turning to the physiologic side of ophthalmology, it may be noted with regard to the growth and nutrition of the eyeball that these are strikingly determined by inherited tendency, and are markedly perturbed only by accidental influences of the severest type. The great mass of eyes approach marvelously near to a normal standard, independently of use or of influences affecting general nutrition. This is illustrated in the retinal development of eyes, the seat of congenital cataract; in the full growth of the eyeball among influences that stunt the general body growth, in the maintenance of function in spite of extensive wounds, and in the strong resistance to the extension of suppurative processes.

In view of the slight perturbation caused in the nutrition of the ocular tissues by moderate influences, it seems easy to understand why physiologic experiment upon the eye has thrown little light upon the normal processes of general nutrition. The influences of sugar and naphthalin in causing opacity of the crystalline lens remain after many years phenomena almost completely isolated and not well explained. The opportunity for the experimental study of pharmacology and of processes of nutrition which seemed to be opened by the discovery of the ophthalmoscope has so far proved rather disappointing.

Pathology. The disturbance of the orderly course of nature within the eyeball is, however, only a question of the adequacy of the disturbing force; and causes capable of producing pathologic results may here be studied through the characteristic series of their effects. The transparency of the ocular mediums enable us to watch undisturbed the usual course of pathologic processes within the eye. This has been of highest value in giving exactness and definiteness to some of our ideas regarding pathology. In the way of contributions to exact knowledge of the processes of exudation and resolution that attend inflammation, and of advanced knowledge of vascular and nerve lesions, much must be credited to ophthalmology. Yet the opportunity it affords for the study of pathology, experimentally or clinically, has thus far been utilized by few, and along comparatively narrow lines.

General Medicine. Ophthalmology has the closest relations with all other departments of medical and surgical science. The general tissues which make up the body at large also enter into the eye and its immediate surroundings. They are here liable to the same morbid changes, and in some measure require the same applications of therapeutic forces. The infections, acute or chronic, have their characteristic ocular manifestations. The degenerations may here be traced, many of them with more minuteness and from an earlier stage than is possible in any other organ. It would be easy to spend time in outlining these relations of ophthalmology which have been the subject of treatises on the eye in relation to general diseases. But it was the "Father of Medicine" who pointed out, "art is long and time is fleeting." Omitting any such general survey of matters which have already claimed considerable attention, let us trace, as equally instructive examples, a few of the newer or less commonly noted relations of ophthalmology.

Bacteriology. Great interest attaches to observations that have been made in the region common to bacteriology and ophthalmology. The pathogenic action of microörganisms can nowhere else in the human body be so readily, directly, and continuously studied. Already the known bacterial flora of the eye, both normal and pathologic, is a large one; and the characteristics and relationships of some of the organisms found there have been quite widely observed and commented upon. Valuable studies of the actions of bacterial toxins upon the living tissues of the eye have been made by Morax of Paris, and Randolph of Baltimore. But their observations are so far from being conclusive that they call for additional investigations to reconcile them.

The identity or non-identity of certain related forms, as the diphtheria and the xerosis bacilli, are of equal interest and importance to students of both sciences. The observation that the same clinical types of inflammation may be associated with the presence or unusual abundance of totally different forms of bacteria, as the pyogenic staphylococcus, pneumococcus, diplobacillus and xerosis bacillus, has been made by many different workers in this field. It raises the questions, what is the essential relation of these organisms to the inflammatory process, and is that relation necessary or merely accidental?

In the eye we have admirable examples of inflammation due to nonbacterial causes, like the retinitis following the excessive use of the eyes, or exposure to excessive light; the choroiditis attending myopia; and the inflammations of the conjunctiva and lids due to eye-strain. Have such pathologic processes any necessary relation to bacteria whatever? What other processes resembling reactions to microörganisms may be reactions to unknown causes quite unrelated to bacterial invasion? It may be suggested that certain forms of ocular disease, such as "Parinaud's conjunctivitis" and "vernal conjunctivitis" ought to be carefully studied for a possible connection with microörganisms other than bacteria.

Neurology. The relations of neurology with ophthalmology are so extensive and so intimate that the boundary between them would vary enormously with the taste or training of the individual who undertook to delineate it. *Die Neurologie des Auges*, of Wilbrand and Saenger, has already reached some 1500 pages and promises to extend indefinitely. Of the twelve pairs of cranial nerves, six are distributed partly or entirely to the eye and its appendages. Peculiarly intimate relations and analogies existing between the retina and the brain give to observations made upon the former a unique scientific interest and value. Then, too, the dependence placed upon the visual function in nearly all occupations and amusements gives it a predominant influence upon the general condition of the nervous system.

Fatigue, neurasthenia, excessive irritability, sluggish and defective development of the higher centres are likely to be very closely connected with abuse or defect of the visual function. The term eye-strain may be loose, indefinite, and faulty, but behind it stands an entity of enormous scientific and sociologic importance. Those who have most strongly emphasized its importance may sometimes have betrayed narrowness of view, and a disposition to reason from mere plausible hypotheses; but the known facts with regard to the influence of abnormal use of the eyes upon the functions of the general nervous system justify more general attention than has yet been paid to them.

Psychology. In the motor and sensory phenomena attending eye-use and eye-strain, we have an open path to intimate experimental knowledge of the general nature and relations of nerve actions and states, both normal and pathologic; and may make the closest approach to objective knowledge of the phenomena of consciousness. One need have but a limited knowledge of ophthalmology and neurology to travel this path and bring back results of great value, as did Joseph Le Conte. Other similar investigations would yield additional matter of high interest for its relations to psychology. Close observations of form, as modified by lenses and prisms; and of color as modified by contrast, and preparatory treatment of the retina, are open to all normal-sighted persons. The careful study of these elementary perceptions must furnish an essential stone for the future edifice of mental science.

The ordinary subjective tests of refraction, which occupy so large a part of the time of every practicing ophthalmologist, furnish data which, carefully selected and arranged, would be of much importance in psychology. The response to the simple test of improving or impairing vision by a change of lens shows characteristics constant for the individual, but which vary widely in different persons. The routine which any one adopts in the subjective testing of ametropia furnishes the fairly constant conditions of experiment calculated to best bring out class types and individual peculiarities of reaction. Surely some ophthalmologist interested in this matter will place some of this material at the command of students of mental science.

Laws of Heredity and Congenital Variation. Attention should be called to the fact that ophthalmology offers an important and promising field for studies of the laws of heredity. I have already referred to the tendency exhibited by the tissues of the eye to adhere strictly to type, in their development and in their resistance to accidental influences. Already enough has been observed to warrant the supposition that, in the eye, departures from the normal type are themselves apt to be typical. Take the well-known facts regarding congenital defects of color perception. The similarity of the disability in enormous numbers of cases, and the tendency to descend to grandsons, through the daughters only, are strongly typical. Such typical instances would seem to promise most for an elementary knowledge of the laws of heredity — those laws which have the widest and deepest importance for the sociology of the future. It must be mentioned, however, that this law of descent through the female to the male does not apply universally. We have in ophthalmology enough groups of exceptions to quite limit and define its scope.

The range of ophthalmic observations already available in this direction is a wide one. The congenital anomalies of the eye and the individual peculiarities it may present, as to color of iris, pigmentation of the eyeground, distribution of vessels, and especially anomalies of refraction, as well as the ocular diseases, have been well worked out, and they are capable of comparatively exact notation and record. Statistical studies regarding them, extending over family or race groups, can be relied on as giving facts of definite value. There are already accumulated many observations of great interest in this connection. The reversion to an ancestral type of pigmentation, in retinitis pigmentosa, the striking condition of amaurotic family idiocy, the predisposition of the Hebrew race to glaucoma, and of the negro to phlyctenular disease, and the comparative freedom of the latter from trachoma, lachrymal obstruction, and strabismus, are instances of a long list of ophthalmic facts that will help to reveal laws of congenital variation and heredity.

Education. From the field of ophthalmology we can bring suggestions of radical importance as to methods of primary education. The educative treatment of squint is truly an educational process; and of the simplest and most definite kind. How development of power and skill goes on under it may well claim the attention of the philosophic teacher.

In congenital word blindness, to which attention has been directed of late years by Hinshelwood and Nettleship, we have a suggestion of the obstacles that may lie in the way of the ordinary training of children. A bright, exceptionally successful teacher told me she had devoted three months to the attempt to teach an apparently bright and active boy of over six years the names of the first three letters of the alphabet, and had failed in that time to fix either of them in his memory. I have encountered two of these cases of inability to name the letters seen, although the alphabet could be repeated forward or backward by rote. In both of these cases, as in most of the other reported cases, this disability subsequently disappeared. Evidently there is a time to teach the alphabet and a time not to teach it. In these cases the times varied widely from the normal standard. How many other mental capacities are there the development of which may be exceptionally early or long delayed? How often is the usual order of development reversed? The complexity of the relatively simple act of vision, its inability to render a certain service because of the retarded or imperfect development of a subsidiary power, should be enormously suggestive to the student of pedagogy.

The ophthalmic history of our schools enforces a lesson that needs to be remembered in every application of educational science. By the training given to and through an organ, and intended to perfect its powers, it is possible to render it functionally worthless. The connection of myopia with the educational process of a certain kind is as well established as the connection of choroidal atrophy, retinal detachment, and cataract with myopia. Then, too, the curriculum and conditions of study which leave the eyes of one scholar unharmed ruin the eyes of others. Will not the analogy between eye and brain carry over the ophthalmic observation as another important suggestion to those who study the theory of education, and work out the educational schemes to which young persons are subjected?

Preventive Medicine and Public Health. It requires no stretch of imagination to apply the observed facts regarding the deterioration of the eyes during school-life to the service of preventive medicine and public health. The separate statistical studies of school-children's eyes are now numbered by hundreds or thousands. Some are of much higher value than others. But taken together, they afford a broad and substantial basis for the conclusions: that as schools are now conducted throughout the civilized world, school-life taxes the eye to near its full capacity for active work; that unfavorable influences, like insufficient light, uncorrected ametropia, or impaired general health, render the strain of school-life disastrous, and cause the eye to be permanently damaged. That merely the normal requirements of the body during a stage of rapid development may cause break-down under ordinary school-work, with comparatively favorable conditions; and that when working to near full capacity, individual needs and peculiarities must be taken carefully into account. The enormous aggregate of disability and suffering, brought about by disregard of these conditions of maximum effective work, make these studies of the eye under school-life very important to those who labor in the field of preventive medicine.

These studies of the eyes of school-children also have for those who study abnormal psychology the suggestive value of very definite and accurate observations in a related field. It is chiefly because of the analogies of eye-strain and brain-strain that we cannot admit extravagant claims for the influence of the former in causing all the ills that the nervous system can manifest. If correction of errors of refraction will not prevent all sorts of neuroses and psychoses, the study of eye-strain and its prevention will throw as much light upon the nature and prevention of brain-fag and nerve-strain as any line of study open to the worker for the prevention of such conditions, be he neurologist, teacher, or social reformer.

In another and quite different direction the straight course of the ophthalmologist, working at his daily routine, carries him into the domain of public health. The group of contagious inflammations of the conjunctiva, especially the still indefinite condition called trachoma, are of enormous importance for their bearing upon public health. Social customs, the regulation of immigration, and the economic and educational problems raised by blindness, are all intimately interwoven with the recognition and treatment of these diseases.

Training of the Worker. Finally, an essential relation of each department of science to other departments is the educational relation. This vast accumulation of observed fact and analogy, of connected cause and effect; this mighty web of interweaving generalization, which our Congress of Arts and Science attempts imperfectly to reflect, — this huge phenomena of modern science, — is of value chiefly as it becomes possible to transmit it from generation to generation. It is the application of knowledge to the needs of men, and the answering of the questions which perplex them, that quickens it and vivifies it — that renders it prolific and immortal. Ophthalmology the science is vitally interested in the training of those who apply ophthalmology the art. The greatest service will be rendered to it and through it to mankind by that institution of learning that will establish a broad, well-planned department of ophthalmology for the thorough training, both optic and physiologic, of those who are to apply its accumulated facts and generalizations. The progress of ophthalmology is to-day seriously impeded by the lack of rounded education in all directions from its essential centre.

Clearly it belongs among the medical sciences. It can continue to grow and prove fruitful only through its connection with their common educational root. But it differs from all other departments of medical science. And that difference, involving a good working knowledge of mathematics and skill in minute observations and delicate manipulations, requires that the specialization in the training for it shall be great, and shall begin early. Difficulties in the way of the required specialization will suggest themselves to any one who has struggled with the problems of medical training. But many of them will disappear as the educational scheme is made to take its proper relation to the peculiar individual needs of each student. As we learn to furnish each growing mind conditions for its best development, the difficulties of teaching a specialty will grow less. When we have given up that barbaric ideal of forcing a living consciousness into a set mold, we shall get away from the notion that an ophthalmologist can be best grown in the region of general surgery, and when ready to bear fruit in that field can be safely transplanted to the outlying clearing of ophthalmic science, where he seems to be needed.

The process of obtaining educative material must be broadly selective. There must be selection on the part of the teacher and selection on the part of the student. We must learn the lesson that the achievements of the race outrun the possibilities of the individual. Even in the free atmosphere of thought, if we take some, more must be left unbreathed. Not that what is taken is of any better quality, simply that it is nearer and can be utilized by less waste exertion. So for each student certain things lie near at hand, within the easy reach of his interest. They may be no better in the abstract, and yet they are better for him. To drag him away from them to seek more distant mental pabulum is to waste a part of his life. In this matter of education, economy of vital force demands that we respect the possibilities and limitations of the individual.

Upon a thousand fields of discovery eager workers push back the ever-widening margin of the unknown. In a thousand laboratories crude fact, treated in the crucible of experiment, is yielding its gold of wisdom. Analysis opens all doors and probes all secrets. Meanwhile fancied boundaries and limits disappear, systems of philosophy fall to pieces, lie in historic fragments for a little time, and then are forgotten. But there are not lacking higher synthetic movements. On the one side becomes more and more clear, order, eternal and infinite, while on the other rises ever more dominant the developed thinker and worker — his union of knowing with doing, the human expression of a divine synthesis.

THE NEW OPHTHALMOLOGY AND ITS RELATION TO GENERAL MEDICINE, BIOLOGY, AND SOCIOLOGY

BY GEORGE MILBRY GOULD

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The distinction between what may be called the old ophthalmology and the new is one of almost unique clearness, as compared with that of other departments of medicine or science. Especially in medical practice, the modern status has usually grown out of the older and oldest by infinitesimal increments and gradual modifications. In opthalmology it is not so, and this fact explains why there are such profound differences of opinion as regards the claims of the new. Although both are usually practiced by the same men, they may be, and often are, as distinct in origin, theory, and practice, as, *e. g.*, are otology and ophthalmology.

The "old ophthalmology" was, and is, concerned with inflammatory and surgical diseases alone, remaining ignorant of and indifferent to such relations as might exist between the eye and the general system, except as regards those minor and few diseases which arise in the body and then affect the eye. Ocular inflammations, ocular operations, and the ocular results of systemic disease — these were the limits of its interests. Even in recent text-books on medical ophthalmology, there is no thought of any other relations of general medicine and ophthalmology than those morbid ocular ones originating outside. That the eye is the starting-point of systemic disease was unsuspected. In the latest, greatest, best, and most official text-book on general medical practice, that of Allbutt, there is not a word, from the first page to the last, which hints at the ocular origin of any systemic disease, not even of headache. In the text-books of general medicine by Continental authors there is the same official ignoring of the claims of the new ophthalmology. In America also most of the text-books either ignore entirely, or, what is worse, list the remote causes of one or two systemic symptoms as possibly due to the eye, but so mechanically and inattentively as to turn the student aside more effectively than the silence of the utter ignorers. The "praise" is very "faint" indeed, with which they condemn.

The new ophthalmology finds its objects of study and interest precisely in these systemic results of ocular conditions. I do not mean in such ways as the circulatory or metastatic transfer of inflammatory or infectious diseases from the eye to other organs, nor to the extension of localized inflammations to adjacent or even distant ones. That is another matter, and of it the old ophthalmology took sufficient cognizance. The field of study of the new ophthalmology is topographically well defined, its title clear, its methods, instruments of culture, the seed, and the crop itself, distinct, both genetically and evolutionally.

The abnormal conditions of the eye which set up morbid systemic results may in strictness scarcely be called abnormal except by a strain put upon the word. At least they are *per se* not morbid. They might better be called physiologically aberrant or variant. They do not originate in inflammatory or pathologic conditions, but simply in optical ones. But for us all physical optics leads to physiologic optics. Primarily and fundamentally it pertains to the eye as an optical instrument, but as a living one, a physiologic camera obscura. If the photographer's camera had an elastic lens instead of a rigid one, and if its refractive power were spontaneously governed by the desire of the camera for an accurate focus of the picture, the analogy would be almost perfect. But the photographer's camera can neither direct itself, nor renew its own sensitive plate, so that in spontaneous choice of scene, change of focus, and renewal of sensitive plate, the living camera is superior to the dead one. The natural difficulties of the choice of scene and of the resensitization of the plate have been beautifully overcome in the eye by the God of evolution, but other obstacles have not been overcome. The ocular camera, for instance, is double, and stereoscopic, and accurately to superpose the images of both cameras is frequently impossible even after ages of workmanship. As all physiology leads to pathology, so, for physicians, all physiologic optics ends in pathologic optics. The twelve ocular muscles have a highly complex and skilled task; hence heterophoria and strabismus. Moreover, the spontaneously elastic lens grows inelastic in forty-five years, and presbyopia, at least before the days of spectacles, was a frightful tragedy. Lastly, the transparent lens could not formerly retain its transparency in old age, and the blindness from cataract at the end of life has not yet been entirely prevented.

But the chief difficulties of the mechanic of the living camera were to secure to 1,500,000,000 human beings, and to their successors in each generation, eyeballs which did not vary more than about $\frac{1}{300}$ of an inch from a given diameter, and to make all corneas of the same radius of curvature in all meridians. These difficulties have been so great that there has probably never been such a mathematically perfect and optically exact pair of eyes in the world. Those chosen by natural selection, the elimination of the unfit, and the mystery of heredity to survive and to repeople the earth, have been such as were not so widely variant as to disqualify their possessors for work and service; and the majority of their children, those now living in the world, have eyes so near accuracy in optical dimensions as to render their owners at least partly functional in the evolution process. This almost infinitesimal variant of $\frac{1}{300}$ of an inch, the thickness of a sheet of paper, in eyeball measurements may throw the unfortunate possessor out of the struggle for existence, so far as perpetuation of the race goes, at least in civilized life, and for some occupations, or it may render him a most pathetic sufferer. I say it may do so, not that it does do this invariably or generally. The simple law is that the greater the ametropia the greater the certainty that it will do so, and the more limited the range and choice of occupations. The lower, not the positively lowest errors of refraction, however, in civilization are those which in moral persons cause the greatest personal pain and suffering. The high errors brutalize, immoralize, and exclude the owner from most occupations; the lower cause pain and illness.

Eye-strain is the unfortunate and inexpressive term that has come into use for the results that follow the attempt of the eyes, brain, and corelated organs to neutralize the defective function of the optically imperfect eyeballs and mechanisms. The optical defect is not morbid; it is at best pathogenic, secondarily or indirectly, not primarily. Its secondary effect, the straining of physiologic muscles and nerve-centres, is not in itself necessarily pathologic. But it illustrates, and best illustrates, the great truth which textbooks, teachers, and medical science itself, are sadly prone to forget, that abnormal physiology is the origin of most pathology. Unnatural action and over-action start the morbid function which finally lands the physiologic upon the post-mortem table. To ignore this truth is itself pathologic pathology; to scorn it is to add unscientific sin to the symptom-complex of the scientist's disease. It is gratifying to find a reaction taking place — the beginnings of it at least. The magnificent paper of Dr. Putnam of Boston, read at this Congress two days ago, is a hopeful sign of progress. I am sorry he omitted the most striking illustrations of his thesis at his hand, the production of headache, migraine, nervous, mental, digestional, and scoliotic diseases, by eye-strain. The etiologic agency in these cases is both organic and functional, according to the point of view, but — and for this he contended most warrantably — it is preeminently physiologic instead of anatomic, — at least not in the sense given that word by the pathologist of the past. The pathologist of the past has, indeed, completed his work. The great need of the future is physiologic pathology.

It should be noted that as eye-strain is itself simply functional,

— if the word, as I think, is still permitted, — not organic, so its results are at least primarily the same. Headache, the paroxysmal neuroses, many nervous and psychic disorders, epilepsy, chorea, migraine, sick headache, gastric, digestional, and pelvic disorders, dermatoses, influenza, anemia, denutrition, etc., when due to eye-strain, are at first and essentially purely functional. Even those more severe diseases, such as spinal curvature, appendicitis, pulmonary diseases, exophthalmic goiter, etc., which are sometimes directly and indirectly the results of eye-strain, are at first characterized by a peculiar stage of functional and remediable disorder, preceding the organic, inflammatory, and incurable one. There are valuable and practical lessons to be gleaned from the fact of the origin of eye-strain in optics at once historic, physical, and physiologic. There is the observation that medical science and pathology did not discover it. The science of physiologic and pathologic optics came to medicine almost entirely from without. It is the gift of students of physics. Even when physicians busied themselves with it they did so purely from their interest in vision and clear-seeing, not from that of pathology. Astronomers, physicists, and opticians presented their gift to medicine. Even Donders had little or no thought of the extension of the practical science made by the practical American ophthalmologist. The earliest refractionists — we must use the word — more or less accidentally and incidentally discovered the facts of the relief of systemic diseases by their spectacles. The patients made the discovery that their headaches and nervous symptoms disappeared when they wore their astigmatic lenses, and they came back and told the astonished and delighted oculist about it. Mitchell, not an oculist, heard the story from Thomson, and he told the profession about a little of it. The profession would not listen and utterly ignored it. For several hundred years the official profession would not even have anything to do with the spectacles which the non-professional invented. It allowed Franklin to invent the bifocal lens and failed to adopt it for a hundred years. There are to-day neurologists, diagnosticians, and physicians of international renown who wholly deny that eye-strain causes systemic reflex diseases of any kind. In 1904 a special meeting of the New York Academy of Medicine was held in which great neurologists and ophthalmologists vied with each other in ridiculing the absurdity. It is no wonder therefore if the stone which the medical builders refused should become the corner-stone of the temple of the opticians. These gentlemen naturally think they have a right to practice the art and science of refraction. Those who scorn the new ophthalmology would in fact reduce the refractionist to an optician. It is a costly blunder which the profession will resent and unlearn. Because refraction is medical art and science in the strictest sense of the term, one indeed requiring the highest intellectual qualities and hence their claim can never be allowed; the profession must therefore now wage a hundred year war which it might have prevented against an enemy which it might have made a friend and ally.

What are the relations of the new and old ophthalmology? They are most intimate sociologically and clinically. In a word, the scientific correction of ametropia prevents almost all inflammatory and surgical diseases of the eyes, — I should say about nine tenths of them. It will not, of course, prevent the few ocular results of systemic disease, such as albuminuric and diabetic retinitis, optic neuritis, toxic amblyopias, etc., but such things are uncommon, and not seldom the systemic trouble had its individual grounding in morbid ocular function. The greater proportion of ocular diseases are those of the extrinsic muscles; inflammations of the lids, conjunctiva, cornea, and iris; glaucoma; high and increasing myopia; and cataract.

As to the external muscles, there is now an almost exceptionless agreement that heterophoria is due to uncorrected or miscorrected refraction anomalies, and that the plunge made into tenotomies, graduate, undergraduate, or postgraduate, was into a blind alley of error and waste which has done irreparable harm to true ophthalmology by making the professional and lay world suspicious and even contemptuous. The heterophoric trouble is innervational in nature and refractional in origin.

As to strabismus, the same truth is at last becoming manifest and admitted. A recent English book, Browne and Stevenson, on the *Squint of Children,* is a striking proof. Get glasses on the child early enough and there will be no squint. Even when the fatal delay has been negligently permitted, the operation does not do away with the necessity for the spectacles, and there are some of us "extremists" who contend that the operation is of little or no good even at the late date.

With the exception of relatively few cases, due to trauma, infections, malnutrition, etc., blepharites, conjunctivites, and keratites, are of eye-strain origin. When one sees a few thousand cases of spontaneous recovery after the patients get proper glasses, the truth needs no further mention.

As to iritis and glaucoma, did any skilled refractionist ever see these diseases appear in eyes which for years previously had been outfitted with right correcting lenses? It may be that such cases occur, but observation shows that the eye which is morbidized by eye-strain has such low resisting power that only a slight inciting cause is needed to develop the otherwise powerless hint.

Concerning retinal and choroidal diseases it is also a truism that they are usually caused by the ciliary strain of uncorrected ametropia. The "woolly," hyperemic, and suffering retinas, the "pepper-and-salt," unhealthy maculas, the abnormal pigmentations, noted ophthalmoscopically as the result of long-continued eye-strain, are suggestive and characteristic.

There is one refraction anomaly, high or malignant myopia, which is the direct consequence of disease of the eyeball. Does any one now doubt that this, the stretching or stretched eyeball, is the result of ametropia? If so, he should go to Germany to live. And why does the lens so often grow opaque in the old? Why, it would be better asked, does it grow opaque toward the end of presbyopic failure? The suggestion comes that it is at least partly because of the denutritive conditions set up by the severe strain of presbyopia added to that of preëxisting ametropia. This theory derives clinical support from the fact that cataract does not arise when the eye has been kept in an optically correct, healthy, and physiologic condition for twenty years before the cataract age.

And thus the good American motto, *e pluribus unum*, applies to ophthalmology as well as to statesmanship. In these many diseases of the eye there is often at last but one disease. There was plainly an over-hasty recourse to surgery when the surgical disease could have been prevented. As has been well said, an ancient hunger for the miraculous has come down to our times and to our medical science, and operation is the modern medical miracle. At last we have begun to see that prevention is better than cure, and the ophthalmic surgeon is becoming the refractionist. In the same way the ophthalmic therapeutist is disappearing to return immediately as the preventer of disease, the keepèr of good eyes good. Therapeutics is fast merging itself into prophylaxis, and the practitioner of medicine is becoming the hygienist. It is a sort of benevolent suicide of the old ophthalmologist for the benefit of his heir, the well-insured new young man. It is fortunate that the new and the old science are in reality carried on in America by the same practitioners so that no rivalry or ill-will can take place. For a time, to be sure, the dual ophthalmologist may privately discuss with his conscience the question as to whether he will undertake to prevent the strabismus of the little one, and the cataract of the presbyope, or operate later, etc., but in this and many other similar instances I do not contend that the old ophthalmologist is Mr. Hyde, although I am sure that the new one is Dr. Jekyll.

The unity of the organism and the interdependence of all functions is the dominating and molding truth of medicine, the monism of physiology, the evolution-principle of medical science and practice. No organ lives to itself alone; there is no function that does not influence every other. This is the truth which disallows a narrow specialism, prevents the exaggerater from becoming an extremist, and forbids the extremist from becoming a hobby-rider. In obedience to it, the specialist must always be on the sharp lookout for all the lines of cause and effect which may subtly run back and forth, either way, between the diseases of his chosen field of study and that of all the other specialists. We are, in truth, all of us specialists nowadays, the general physician fully as much so as any other. While knowing profoundly one specialty, as willy-nilly we now must do, it is our common duty to maintain a keen outlook over the work of others and preserve a large sanity of mind, and a genuine sympathy of feeling with our colaborers in all other fields. The direction to speakers at this meeting is to choose out and emphasize the relations running between their specialties and those of others, between one science and the other sciences. We are to bind into unity, or preferably discover the number and nature of the existing bonds which make the organism one, and its parts interdependent, and which resolve all organisms into a universe.

The relations which exist between refraction anomalies and general medicine are almost solely of one kind, — those, namely, in which the ocular condition is causal. There are very few bodily conditions or diseases that influence the ametropia.[1] Large changes in general body weight, I have demonstrated, do so, a decided increase of fat tending to lessen the anteroposterior diameter of the globes; an extensive decrease of fat, conversely, lengthening the eyeballs. I have also noticed that after a severe illness refraction changes will probably be found. Other illustrations may be omitted.

The eye and ear have extremely few, if any independencies, and they are relatively unimportant. And yet an expert might write an interesting monograph on the subject. One would say that the dentist and oculist had little in common, and yet I have had more than one patient who had violent toothache in sound teeth whenever he read or wrote five minutes.

The specialist in diseases of the upper air-passages must never forget the oculist. It is a significant fact that eye-strain patients locate their headache directly in or behind the frontal sinuses. We list them as frontal, but understand thereby that the forehead is the location of the pain. For many years I had noticed that there was a suspicious relation between eye-strain and frontal-sinus disease, and in several patients I had definitely traced it. Dr. Phillips of Buffalo has made a close study of ten such cases in which the sinus disease was clearly due to eye-strain.[1] Reflex congestion of the upper air-passages, pharyngitis, laryngitis, aphonia, common colds, and influenza, may be, and more frequently than supposed, due to eye-strain.

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[1] Although one well-known neurologist and one orthopedist have said that the eye-strain is a result of the systemic disease rather than the reverse, — an amusing betrayal of a lack of knowledge of what ametropia is!

In general surgery nothing, a short time ago, would have seemed more absurd than to say that eye-strain could at least prevent surgical disease and operations. Yet Dr. Robert T. Morris of New York,[2] whose character and professional standing need no setting forth, writes as follows:

"A very large group of cases of intestinal fermentation is dependent upon eye-strain. These cases are perhaps quite as often overlooked as any others, but as soon as we have all become familiar with the external signs of eye-strain, fewer cases will get to the surgeon with the diagnosis of abdominal disorder. The ones that I see are sent to the office most often with the request to have the appendix examined, because the distension of the cecum is apt to cause more pain than distention of other parts of the bowel and attention is attracted to this region. If there are external evidences of eye-strain, these cases are referred to the ophthalmologist, along with my cases of nervous 'dyspepsia' and 'gastric neuralgia,' and some of the most brilliant results that I have observed in any kind of medical practice have come out of the treatment that was instituted."

If an oculist had first made such a statement, the grin of derision would have extended across the face of the Continent. Because the general surgeon thus annually turns away from his office thousands of dollars' worth of operations, it derives at least the merit of unselfishness.

There is no truth in medicine more certain and demonstrable, although the gastrologist has not heard of it, than that eye-strain produces anorexia, denutrition, intestinal fermentation, constipation, and many disorders of the digestive organs, including, especially, the liver, although in no book on stomachal and intestinal diseases is the subject mentioned. If so, it is, of course, admitted that the surgical diseases secondary to such disorders may be ocular in remote origin, and the warning may not in future be safely unobserved by the appendicitis specialist, the gastrologist, the gynecologist, etc. Within a year a famous medical journal has editorially stated that all obscure gastric symptoms demand the excision of the gastric ulcer. That is, surely, surgery gone mad.

In orthopedic surgery a new causal relation has most recently been discovered between eye-strain and spinal curvature. Scoliosis begins in childhood and adolescence, as spinal curvature, and in thousands of patients the spinal disease is unsuspected by child, parent, and doctor. Within a few months I have discovered thirty or forty cases of tilted heads, most of which caused or might cause secondary or compensatory scoliosis, and all due to an axis of astigmatism (about 15° unsymmetric, and to one side of 90° or 180°, in the dominant, that is the dextral eye in the dextromanual) which compelled an habitual lateral inclination of the head in order to see plainly. And the compensatory curvature of the spine induces a score of other systemic diseases. We formerly allowed our patients to tilt the head while making the refraction tests, and so missed locating the astigmatic axis correctly.[1] By keeping the head vertical during the testing we now apply glasses that keep it straight afterwards, and when the spinal curve is still functional we likewise straighten it by glasses alone.

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[1] *American Medicine*, 1904.

[2] *Medical Record*, December 26, 1903.

No pediatrist henceforth may forget the eyes in all of his patients over eighteen months old. The chances are high that, without other definite and easily ascertained cause exists, eye-strain is the source of mischief in the child which suffers from night-terrors, breakfast anorexia, tics, chorea, nervousness, disorders of digestion and nutrition, irritability, headache, etc. I have instantly cured nocturnal enuresis in such children by spectacles alone. Alert-minded pedagogists are fast becoming aware of the tremendous rôle of eye-strain in the health and success of their pupils. As every year of school-life passes, the proportion of diseased pupils increases, until in the upper grades it may rise to 60, and even 80, per cent; it is 40 per cent, on the average, in Columbus, Ohio. And the diseases are precisely those which every capable oculist knows are often due to eye-strain. The rule is so certain that discerning teachers know that those pupils who are one, two, or three years behind their classes, have severe eye-strain, and without further inquiry they are sent to the oculist. There is hardly a page of that magnificent book on *Adolescence* by Dr. G. Stanley Hall, that does not need rewriting with this new knowledge — unfortunately and strangely ignored — in the mind of the writer. Its splendid power and truthfulness could have been doubled had its gifted author looked into the vast existing literature, written by capable and scientific minds, confirmatory of the rôle of eye-strain in school-life.

In neurology there is almost no limit to what the refractionist may justly claim. And posterity will allow it, although the neurologist of to-day may often be unconscious and contemptuous of the truth. Neurasthenia and hysteria he claims as his exclusive possession. Private sanitariums or rest-cure establishments may be of limited and infrequent service for chronic patients whose vitality and resisting powers have been worn to a thread by a half-life of torture for which no therapeutics availed. But even the ordered rest-cure could often be avoided by correction of eye-strain, and in perhaps 75 per cent of cases the neurasthenic break-downs and chronic hysterias could have been prevented by attention to the matter in adolescence. Not infrequently it is plain that the resting is curative because the eyes are rested. With reading and writing interdicted there are often astonishing cures: with resumption of reading and writing, relapses and returns to the sanitarium are required.

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[1] An excellent rule of ophthalmic office-practice is that when we fail to cure eye-strain results by our glasses, it is perhaps because we have allowed the head-tilters to hold their heads as they pleased during the tests.

Every sensation and its every correlated motion is an example of reflex action, and yet there are those who airily scoff at the very possibility of reflex neuroses and other diseases due to reflex action. There are those who speak scornfully of mysticism and mystery in medicine, while satisfied with a practice which reduces itself to diagnosis and naming unknown mysteries as migraine, neurasthenia, hysteria, psychosis, etc.

Psychiatry seems to have reached the goal of its ambition, — theoretic classification, nomenclature gone mad, and therapeutic nihilism. Diagnosing and naming a morbid mental condition as "a katatonic state," "major psychosis," "melancholia of involution," "psychical tonus or contracture," "dementia precox," "*forme fruste*," "manic depressive insanity," "confusional psychosis," "psychoneurosis," "pseudoneurasthenia," "mysophobia," "topoalgia," "neurasthenical syndrome," etc., — all of which terms are culled from one short article, — seem to end in the air so far as bettering conditions.

Who has examined the refraction of the insane? What patient with extreme eye-strain or migraine has not feared insanity? The sanest of men, Parkman, was pronounced insane, and so was Wagner and others, by great authorities, at the climax of their sufferings. Was not Nietzsche's "atypical paralysis" intimately connected with his most evident eye-strain? A competent oculist finds the majority of the young criminals of the Elmira Reformatory afflicted with so high a degree of ametropia as to make study, reading, and writing, and ordinary handicrafts, impossible. What else could many of the poor boys do but play truant and steal? The statistics showing the relation of crime to truancy indicate that some of both may be due to bad eyes. In 232 cases of suicide, 187 were due to ill-health. About 50 per cent of chronic epileptics have unsymmetric astigmatism and anisometropia, — a surprising ratio of a defect especially prone to upset the cerebral health and balance. And the peculiarity of the diseases of eye-strain is their tendency to produce psychic and emotional disorder, despair, melancholy, etc.

There is scarcely any disease which the general physician or internist is called upon to treat that may not be, and that frequently is not, due to or influenced by eye-strain. The commonest is designated by that silly and meaningless word, migraine. The term has little or no significance nowadays. It is in fact the vulgarization of a misnaming and meaningless designation of a malobserved and trivial symptom, which in the majority of cases is not present, of a widely prevalent and ingravescent disease, with indescribable symptoms, which may, in extreme cases, wreck life and morbidize the mind, the etiology and pathology of which are unknown, the location or organs affected being also unknown, and of which no treatment avails. It is made to cover the conditions indiscriminatingly called scotoma scintillans, headache, sick headache, gastric and intestinal disorders, insomnia, melancholy, etc.; in a few severe cases such patients have all of the symptoms. One symptom, dermatosis, the French physicians learned long ago, is not recognized by modern dermatologists. Severe skin-disorders are not infrequently an indirect result of eye-strain. Migraine is almost always due to eye-strain, and, except in the rarest worn-out chronic cases, it is almost immediately curable by extinguishing eye-strain. It is the commonest of all affections, the great manurer of the ground for other and terminal diseases, the supporter of quacks and patent medicine syndicates. At least 10 per cent of Americans suffer from it, under one alias or another, recognized or unrecognized. The larger number of these, taught by sad experience, have given up the hope of cure, and they are neighbors of the person who says migraine has no relation to eye-strain, and who does not know that thousands are now being cured by two little pieces of glass. Eye-strain effects have a peculiar tendency to periodicities and waves of better and worse. The nervous centres can endure for a time the burdens and irritations laid upon them, but at last give way. This is so of mental states and diseases, and the eye, as psychologists know, is the chief creator of intellect. Hence those diseases or symptoms, when not dependent upon organic disease, like headache, sick headache, fickle appetite, the paroxysmal neuroses, cardiac palpitation or irregularity, chorea, epilepsy, neuralgias, insomnia, colds, etc., which exhibit such waves and troths of exacerbation and depression, may be due to ocular irritation.

A key to many mysteries of disease might be found in a careful classification of such as have increased with civilization as compared with those conditions outside which have been changed during the progress of civilization. Among these changed conditions none can be more noteworthy than the new kind of labor, and the tremendous addition of the amount of it, thrown upon the eye by the printing-press, schools, sewing, clerical, and urban life. No other organ has been subjected to such a change of work and stimulus, and in all other functions the same kind of work is now demanded as before. The eye, however, was brought into function to use in distant vision, and if for near, for but an instant. Osler says that dyspepsia is the besetting malady of this country, due to improper diet, etc., although modern food is many times more certain in amount and good in quality than ever before. It is certain that stomachal and nutritional diseases seem to have recently increased inordinately. What is the cause of this contradiction? One, surely, is eye-strain, which is extremely prone to upset the digestive function. See several thousand cases of nausea, "dyspepsia," loss of appetite, constipation, etc., relieved at once by glasses; see the disease return at once when the glasses are broken, a lens reversed in a frame, or when the refraction changes, and one recognizes the fact of the interrelation.

Allied to this class of cases are those in which the keen ophthalmologist detects more than hints that renal affections, hepatic ones surely, including gall-bladder diseases, may possibly be set up or aggravated by severe reflexes from the eyes to the secretory and eliminative organs. Some day it will be established that eye-strain is a large factor in the production of diseases of the kidney.

One of the more subtle but still easily recognizable methods in which eye-strain works perniciously is by a slow and general denutrition and reduction of mental and physical vitality whereby the resisting powers of the system are reduced to such a degree that it becomes the easy prey of infections and of general and terminal diseases. This makes eye-strain a factor in the tuberculosis and pneumonia crusade. The life-study of patients and their diseases — the biographic clinic — will make such a connection more often manifest. The sad story of the life of John Addington Symonds is in this way suggestive.

The age-long superstition, whereby almost all the diseases of women were traced to the sexual organs and functions,[1] is fast giving way to a new view more in correspondence with facts. That puberty and menstruation should inaugurate a host of terrible evils, and the menopause another legion, is at the least contradictory. The proper name for the cause of many supposed disorders of menophania and puberty is study with astigmatic eyes; that for supposed menopausal woes, is presbyopia. In a large number of instances ὀφθαλμός may replace ὑστέρα as the organ primarily at fault. The oculist and gynecologist should be good friends. The connection between eye and sexualism is known of old, and is a deep and profound one. Love of any and all kinds dilates the pupil, the designation of the grand sympathetic system itself arising from the fact.

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[1] A sad error that much mars the large sanity and lessens the benefits of Dr. G. Stanley Hall's great book.

A certain profound relation of vision and sexualism will some time be established which as yet is unsuspected.

Justly motived, therefore is the question: why has this great truth been so long ignored, and why now do so many reject it? Some of the answers are these:

1. The progress of science has not yet reached the stage that will enable certain minds to see its truth.

2. The conditions of life and professional evolution have made surgery of supreme importance.

3. Organic diseases had first to be studied.

4. The laws and status of infectious diseases had first to be made definite.

5. A mere habit of neglecting the eye and its all-important function and diseases has with some grown into a blind dogmatism.

6. The theory of optics and the elaboration of mathematic formulas satisfied too many minds, and there was no proceeding to the practical application in clinical work.

7. Specialists in medicine, other than ophthalmologists, have overstated the effects of the diseases of special organs.

8. The ophthalmic tenotomist has made unwarranted claims, and so made the profession blind and deaf to the warranted claims of the refractionist.

9. The commercial medical journal plays to the galleries and flatters the prejudices of its readers.

10. Patent medicine venders, drug-sellers, and quackery within the profession carry on the irrational tendency.

11. Suffering and pain are positive, relief and cure negative. The patient therefore is prone to forget the former misery, nor does the physician recognize the cause of the cure by glasses, which is ascribed to fate, *gale répercutée*, the doctor, his drugs, etc.

12. The method of eliciting symptoms and of clinical note-taking is so faulty that the very existence of the chief symptoms of eye-strain is not recognized. The patient thinks the vomiting, the abdominal symptoms, migraine, headache, dyspepsia, insomnia, loss of energy, etc., have no possible connection with the eyes, does not allude to them, and they are thus wholly ignored. Thousands of such cases have been cured by glasses and the fact unsuspected by either physician or patient.

13. The desire for consultation practice, referred cases, professorships, hospital positions, and "success" make the cunning silent, or conservative. "Faddism" and "hobby-riding" charged to a budding reputation are ruinous.

14. Poor refraction work on the part of oculists is the greatest cause of skepticism. Those who do accurate refraction know perfectly well that, broadly speaking, the ophthalmologists of the

world have done their refraction work badly. The logical and pathological conclusions of the labors of Donders, Helmholtz, and others have been practically made only by some American, and one or two European, refractionists. "I sent my patient to the oculist and glasses had no effect on the disease," means utterly nothing. "Is not my oculist a man of the highest renown and ability?" may mean as little. Does this man of renown and ability teach, and in the persons of his patients demonstrate, that so-called "migraine," headache, sick headache, dyspepsia, spinal curvature, insomnia, neurasthenia, anemia, the blues, and the rest of the list, are often, very often, due to eye-strain? Belief in the truth is a prerequisite of ability to cure; and it is absolutely essential to a rigid attention to at least "78 reasons why glasses fail to give relief." From 50 to 75 per cent of glasses prescribed in the world are inaccurate and cannot relieve eye-strain. Then it is also true that fully 75 per cent of the adjusting of opticians is so bad that any possible therapeutic result is not obtained. To be entirely frank, one should add an argument which is, indeed, a two-edged sword, but which needs occasional use to keep it from rusting. It is this : Those who deny that migraine and the many other diseases mentioned may be due to eye-strain have not of course cured such patients in their own private practice. That is a self-judgment which is most severe. Those on the other hand who claim that such diseases are curable by ametropic correction, unless utterly unprofessional, must have cured such patients. If they do not cure they would surely be soon found out and their reputations and practices ruined. They seem to prosper! I heard one astute oculist say that if this absurd skepticism continued a few years longer his fortune would be made. He is very "successful" and is conducting his work in an honorable manner. The enthusiasm and gratitude of a patient permanently relieved of the tragedy of "migraine" or "neurasthenia" are irrepressible.

A corollary is that refraction is not taught, there is not a single adequate and thoroughgoing school wherein may be taught, or wherein there is any outfitting, or attempt to teach, this most skilled, most infinitely subtle and difficult art and science. Two years at least of study, daily, exclusive study and practice,—after the general course in medicine, under expert teachers, and on the part of the best type of student minds, is a too short period to introduce him to the work, and legally to justify him in entering on such specialist practice. An endower and maker of such a school would do the world a far greater service than either Carnegie or Rockefeller have dreamed of doing.

Again the critic may justly ask: Have none, then, recognized and spoken out this much unrecognized truth? Oh, yes, many and good men have done so. There is a vast body of literature produced by clinicians of the best character and professional standing, and it is astonishingly convincing and cogent. It is unfortunately scattered, and hence in part ignored by too many physicians. The last weighty utterances are Dr. Zimmerman's study,[1] and, especially since they are from England, the excellent papers of Dr. Snell,[2] and Dr. Pronger.[3] Hundreds of others might be cited, the testimonies, *e. g.*, of such good professional journals as *The Cleveland Medical Journal, The St. Paul Medical Journal, The Lancet, The Pacific Medical Journal, American Medicine, The Maryland Medical Journal, Colorado Medicine, Science, Mind, The Harvard Graduates' Magazine, Bulletin of American Academy of Medicine, Canadian Journal of Medicine and Surgery, Dublin Medical Journal, Medical Press and Circular, Bulletin of Chicago Health Department, The Practitioner, The Nation, Wisconsin Medical Recorder, Quarterly Medical Journal, Treatment, California Medical Journal, Medical Bulletin, Medical Council, The General Practitioner*, etc.

Of individual opinions a page of names could be easily cited, of men with good professional reputations acquired and to be preserved, such as, for instance, Drs. Jackson and Bates of Denver, Edes of Boston, Southard of San Francisco, Hurd, Reik, Welch, Murdock, and Halsted of Baltimore, Senn, Walker (J. W.), and Westcott of Chicago, Baker and Sherman of Cleveland, Cheney of Boston, Alleman and Prout of Brooklyn, Carmalt and Swain of New Haven, Coggin of Salem, Mass., Bennett, Starr, Pohlmann, and Phillips of Buffalo, Risley, Pyle, Thorington, Hansell, Reber, Zimmerman, Solis-Cohen (S.), Thomson, Fenton, Murphy, Talcott Williams, Hollopeter, etc., of Philadelphia, Callan, Ranny, Carhart, etc., of New York, Van Duyn and Marlow of Syracuse, Taylor of Wilkes-Barre, Würdemann and Black of Milwaukee, Roberts of Pasadena, Ellis and McBride of Los Angeles, Hale of Nashville, Matas and Souchon of New Orleans, and especially the dean of American ophthalmologists, Dr. Green of St. Louis, who for nearly fifty years has been refracting patients and observing the results. I append in a footnote[4] extracts from a personal letter written by Dr. Green, because of its peculiar appositeness.

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[1] *New York Medical Journal*, Nov. 21, 28, 1903.

[2] *The Lancet.*

[3] *Slight Errors of Refraction and their Influence on the Nervous System*, Harrogate: R. Ackrill, 1903.

[4] DEAR DR. GOULD: I have read your two volumes of *Biographic Clinics* with great interest, and have gained much instruction from them. I regard them as a very important contribution to a just appreciation of the distinguished men and women whose lives you have so sympathetically studied.

The fact that the commonest ocular defects may give rise to morbid states such as you have depicted has impressed itself upon ophthalmic specialists before it was recognized and urged upon the medical profession in the classical essay of Dr. S. Weir Mitchell, *American Journal of the Medical Sciences*, April, 1876. In the nine illustrative cases reported in that paper, the trains of distressing and disabling reflex symptoms clearly parallel those analyzed by you in the fourteen

But as optics grow into physiology, and physiology into pathology, so must our pathology merge into biology. How is eye-strain related to the evolution process of living things? The test of the validity

Biographic Clinics, but with this difference: In his cases the dominant etiological factor was discovered before irreparable damage had been done, and relief followed the timely prescription of appropriate glasses; in the lives which you have discussed, relief came only in advanced age, when accommodation ceases from troubling.

To me the central and very significant fact is that the protracted sufferings, always alleviated by rest from eye-work and always recurring with the resumption of studious pursuits, as portrayed in the several biographies from which you have culled, are such as ophthalmic practitioners recognize as dependent, in many persons, on common ocular defects, and as preventable or curable by properly directed optical treatment.

It cannot be too strongly impressed on all intelligent persons, whether physicians or workers in other fields, that the demands made upon the eyes in modern life are much greater than the visual apparatus, when of only average structural perfection, can meet effectively and safely. The lesson which I have learned from forty years of continuous study of the anomalies of accommodation and refraction is precisely in the line of your teaching, namely, that no degree of anisometropia or of astigmatism can be regarded as too small to demand accurate correction in persons compelled to use the eyes continuously, or in patients suffering either from so-called asthenopic symptoms, or from headache or other reflex disorders induced or aggravated by eye-work. Neither can I accord any measure of assent to the notion that a short term of attendance at a postgraduate school, or any period of apprenticeship in selling eye-glasses and spectacles, can qualify an uneducated or, at best, a crudely educated man to do work which often taxes my own powers to the utmost, and in which I find that the continued coöperation of the patient, by returning promptly for further advice when anything goes wrong, and by permitting the necessary periodical revision of his optical correction, is indispensable.

It is surely not an extravagant contention that eyes which do not perform their function perfectly in all respects and under all conditions, or whose use is attended or followed either by local disturbances or by headache, nausea, insomnia, or other reflex manifestations, ought, without exception, to be promptly and critically examined. That such examination will very often bring to light a previously unrecognized ocular defect, and so point the way to urgently needed relief through wearing properly chosen and properly adjusted spectacles, needs only to be stated to command assent. The knowledge that relief from headache may come through wearing glasses is becoming more and more widely diffused; but comparatively few physicians have learned as yet to recognize the protean forms which reflex disorders of ocular origin may take on, or to estimate at its true value the service which a wise and conscientious ophthalmic specialist may be able to render.

The investigation and treatment of functional disorders dependent on structural imperfections of the visual organs call for the exercise of the minutest care, and often of almost infinite tact and patience. That these essential qualifications are sometimes conspicuously lacking in men eminent for their achievements along other lines is also true. Careless or perfunctory refractive work by an ophthalmic specialist will yield no better results than similarly defective work done by persons of inferior scientific attainments and of vastly less reputation. The intelligent and painstaking pioneer work of Ezra Dyer; the invention and employment of new aids to diagnosis by William Thomson; the frank recognition and just appreciation by S. Weir Mitchell of the far-reaching benefits rendered in his reported cases, by William Thomson, William F. Norris, and George C. Harlan; and lastly, the continued devotion to the cultivation of accurate methods by a long line of careful investigators down to the present day, make up a sum of achievement by Philadelphia men which may be regarded as more than sufficient to justify the recognition of a distinctive Philadelphia School.

The personal sufferings of Ambroise Paré and of Percivall Pott were the means of enriching surgical literature by two illuminating chapters on compound fracture. Your early experience of the torments and disabilities incident to a too long delayed diagnosis and correction of a complicated ametropia gives you, also, the right to speak forcibly and with authority.

Were not the Hebrew prophets decried, in their day, as enthusiasts?

JOHN GREEN.

of all medical truth, and distinctively of that we have been emphasizing, is its function in the great incarnation process summed up in the Bible verity, "The word became flesh," and in the consensus of doctrine in the term, Darwinism.

A truth none can deny, but one which all biologists have ignored is this: Vision is the dominant condition of self-motility. Wherever there is an animal that moves in the light, there are eyes. *Ubi motus, ibi visus.* There could not have come into being any except the very lowest animalian organisms unless through the visual function. All nutrition, all safety, all attack and escape, all free-moving and effectual doing, were utterly and wholly by means of seeing. Thus the evolution process was dependent upon and made possible only through the evolution of the eye, both as a precedent and conditioning *sine qua non.*

And few have the most dim notion of the complexity of the organ of vision in man, or of the amazing difficulties of "Biologos" in fashioning and perfecting it. Millions of finger-tips are bunched together in the one-inch cup of the eyeball, from whence run about 425,000 nerve-fibrils to a topographic mechanism of sensation in the occipital lobe. The eye can see an object of $\frac{1}{1000}$ inch in diameter. The cones and rods are only $\frac{1}{10000}$ or $\frac{1}{14000}$ of an inch in diameter, and a million cones at the macula occupy the space of only $\frac{1}{10}$ of an inch space. These crowded finger-tips perceive the shape of the picture and the intensities of the light stimuli of all illuminated objects, of a millionth of a millionth of the kinetic energy of any other physiologic force, and of so short a duration as the 0.00144th part of a second. And out of these infinitesmal waves the sensations called light and color are created. The mechanism which creates them must be in intimate and instant connection with the centres initiating and controlling every other sensation, of every motion, of every muscle of the body. Imagine for an instant what takes place in every animal and human being every day of its existence: a traveler tells of a monkey pursued by another, and running over and through the tops of the trees of an African forest faster than a deer could run on open ground. The flashing repetitive momentary glances of the eyes, before, back, and all about a hundred objects must be coördinated with a mathematical precision to accurate unity and brilliant action of every muscle of the body. Similar perfection of eye and motion has been evolved in every higher animal of the world, and in every savage, and in every child. Your horse avoids all stones and knows, unconsciously, every inequality of the ground before and beneath him, by the like mechanismal unity. Watch little children in play barely missing obstacles and dangers which would mean injuries and perhaps death, with swift unconsciousness. The history of savagery and of civilization is all there and is of the same nature. See with unbelievable accuracy if you would succeed, is the first verse of the biologic decalogue. That is the physiologic Logos which became the biologic flesh.

But see inaccurately and you die, is the antithesis, and the animal which failed to obey perished, inevitably and quickly. The savage did the same; your horse that stumbles is useless; your playing child that hits its leg or trips becomes, at least, a very different child, and a very different man or woman from the others who do not make these visual and coördinating blunders. Such are the backward scholars in schools and, in large part, they are your failures in life, society's expensive degenerates, defectives, and dependents. And they are rapidly increasing in number with every step in civilization, because every such step means the entangling difficulty of added near vision.

All of which — and this is the heart of the matter — all of which, Darwin, a martyr to bad eyes himself, failed to see, and all of which no evolutionist has since caught sight of. And yet it has been one of the large controlling conditions of the evolution-process. For not only has this unity of mathematic optics and physiologic function been the inescapable method of success in the struggle for existence, but it has been one if not the chief mechanism whereby the so-called unfit have been thrown out of the count. Visual imperfection has been and is increasingly becoming one of the dominating causes of the exclusion of the ontogeny from the propagating phylum. This is the fundamental distinction which differentiates the laws of biologic evolution and survival of those with and those without vision. It is the key which will unlock and reveal many of the profound mysteries of heredity and descent which to-day are tormenting the different schools of evolutionists and biologists. Open the door and walk into the long-closed ancestral hall and the mystery of forbear and aftercomer is revealed. How and why we are here is at once plain. None could have been, and we could not now be, the link between the phylum of the past and that of the future, except on the condition of seeing well. Those not allowed to become such parental links were largely those who saw too inaccurately to compete in the beneficent but summary process.

Note well, however, two things: The most perfect organism in the past world of animal and man was useless without, first, this perfection of visual function, cerebral coördination, and muscular response; and, second, the attainment of this optical mechanism was far more transcendently difficult than any other physiologic task. To attain transparency and nourishment of cornea, lens, vitreous humor, and retinal end-organs, to superpose the images of the two eyeballs, to respond to the almost nothing of stimulus, to transmit to brain, to manufacture sensation, to dominate all other cerebral function, instigate and direct all motion — where is the end of the marvelous task! The end is in failure to do any one of these things, and to make that inch-in-diameter eyeball of a spheric perfection which shall not vary by $\frac{1}{300}$ of an inch from the norm. The end is not to have prevented conjunctivitis, traumatism, keratitis, iritis, glaucoma, cataract, retinitis, and other multiform diseases, prone especially to occur in the astoundingly complex and refined organism. The pathology of animalian evolution has therefore been in large part the pathology of vision. The organism otherwise perfect, except as to an infinitesmal visual part, is thrown out by this optical necessity. The mechanism par excellence of the exclusion of the unfit is thus made clear.

And to this now add the consummating and crowning function of vision, — the creation of intellect. Psychology, history, and biology unite to demonstrate that the objectivation of the ψυχή of civilization is almost uniquely by means of vision. The greatest task of all human history was the creation of the letters of the alphabet. It was so difficult that only one race did it, and within one or two millenniums all others have come to a knowledge and use of civilization only through the adoption of the invention. No writing and printing, no civilization. But the letters of the alphabet are conventionalized symbols of pictures or things seen. Add to this that language itself is of identic origin. There has been no speech except to express the result of ocular function. Almost all psychology is summarized as handlings, coördinations, and deductions of visual images, of these and of the motions made possible by sight. Thus every cerebral function, perception, apperception, feeling — most of it, and willing, — that which is effective, surely reasoning and judgment, — all spring originally and constantly, are bound up with, dependent upon, and interdependent with vision.

There is something more than mere imagery and fancy which analogizes the course and phases of these developmental stages to the way of water-flow in the world. Decidedly optical are the sun, cloud, rainfall, and snowfall upon the uplands and mountains whence spring the crystal streams and rivulets of physiology. In them optics becomes function and action, physics becomes physiologics. The lower falling brooks become discolored and morbid when they reach the homes and degradations of man, — physiology becomes pathology. But the stream broadens into the large river of biology with the commerce, the health and unhealth of a continent, until finally the Mississippi sweeps to the mothering ocean of sociology where sail and steam the navies of the world.

Thus all routes and efforts lead to man, and all biology ends in sociology. Our striving is for human betterment: because all medicine is preëminently philanthropic. The beclouded or befogged mariner orients himself by means of an optical instrument, and as the sun and the sun's winds bear the sun-made clouds back to the far-away mountains again, so vision and optical eyes and instruments again complete the morbid and therapeutic circle, the cure which is always beginning and never complete.

My contention is that here is a great means of civilization. It is a profoundly important thing that the hopeful Carlyle of the *Characteristics* should have become the pessimist of *Shooting Niagara and After*. It is civilization's tragedy that Nietzsche should have had havoc played with his mind by eye-strain; that Huxley should have been driven from work at the height of his powers; that DeQuincey should have been an opium-eater; that Darwin should have been able to work but two hours a day with his eyes, and Parkman but a few minutes. Is it not a sad thing that George Eliot and her books, Symonds and his great opportunity, Taine and his great scholarship, should have suffered as they did? Is it not a pathetic source of social misery that 10 or 20 per cent of eyes are incapable of sewing, typewriting, book-keeping, lathe-work, studying, draughting, and a still sadder thing that their owners have no knowledge of the fact, and that they should suffer until "break-down" comes? Is it not an awful thing that from 40 to 60 per cent of all school-children are sickly? That suicide is increasing, insanity and epilepsy incurable, hospitals multiplying, — and taxes, and prisons, and war, and want? A certain, perhaps a large per cent of all these backward school-children, epileptics, prisoners, insane, hysterics, neurasthenics, dyspeptics, have such eyes that glasses correcting their optical defects would bring them much relief, would often have prevented much or all of their tragedy. And the proof is this: put any pair of such spectacles on any one of us, and within an hour there would be headache, giddiness, vomiting, or intense suffering. The cynics and skeptics of "eye-strain exaggeration" can be speedily converted whenever they are earnest enough to try a simple experiment upon themselves. It is a truth awful in its significance that in civilized countries there are millions of people who are good products of the evolutionary mill, who have sound minds and good bodies, but who are partial or complete failures, always with intense personal suffering, simply because of an infinitesimal malcurvature of the cornea, a too long, or a too short eyeball, no greater than the thickness of a sheet of thin paper. It is the little thing that, overlooked by others, makes or mars all undertakings, all sciences, and all cosmic proceeding. The compass guides the ship and without it there would be no civilization as we see it. Without vaccine virus there would be a different world, there could hardly be civilization, and yet it was a generation after farmer Jesty inoculated his family from the teats of the cows in the field before even Jenner dared do the same, and before the best of the profession would have anything to do with it; and to-day there are perhaps a million anti-vaccinationists in America! When Pasteur had demonstrated what Villemin and Davaine had before said was true, the bacterial origin of some diseases, history records that "the doctors, in the great majority, were violently opposed to the germ-theory of diseases. They answered experimental proof with oratory. The less excited among them urged temporizing. The surgeon Chassaignac warned Pasteur that laboratory results should be brought out in a circumspect, modest, and reserved manner, etc." In 1843 our O. W. Holmes conclusively showed that puerperal fever was contagious. We ignored the fact. In 1846 Semmelweiss, of Vienna, independently proclaimed that puerperal fever was due to inoculation by nurse, midwife, or doctor, and that this contagion could be prevented. For this bravery and clinical acumen Semmelweiss was persecuted by his medical brethren, turned out of his professorship, and ruined. In the Paris Maternity Hospital in 1856 64 women died of the disease out of 347 admitted. In 1864 out of 1350 cases 310 died. At last in 1874 Fornier and Budin introduced the "new" views of Pasteur and Lister, and in spite of what Dr. Roux calls the "tyranny of medical education," they were accepted, and puerperal fever disappeared. Would it not have been an inestimable gain not to have persecuted Semmelweiss, and instead, to have examined and tested his theory? In 1888 Dr. G. Martin stated that "migraine" was due to astigmatism, and published proofs. In 1903 and 1904 the *Medical News* likens those who say the same thing to Dowie and Mrs. Eddy, and the leaders of the New York Academy of Medicine call a special meeting in order to snuff out of existence the advocates of such a senseless theory. And yet migraine is due to eye-strain, as any one can prove whenever he wishes, and as thousands of patients will testify whenever asked. Migraine is peculiarly a disease of civilization, increased with every added hour of near-work with the eyes; and civilization is enormously increasing that constant strain of near-work with eyes evoluted during millions of years for a different function.

There is hardly an instance in all history of a great and beneficent medical discovery that was not either ignored or hated and scorned by the official leaders, and by the great part of the entire profession. It was so with vaccination, with anesthesia, the germ-theory of disease, Mendelism, thoracic percussion, ovariotomy, antisepsis in surgery, the etiology of yellow fever and malaria, the serum treatment of diphtheria, Pasteur's anti-rabies inoculations, the humane treatment of the insane, etc.

Now the amazing fact about all of this is its ease of proof or disproof, the passionate hatred with which was rejected a possible source of relief of human suffering, the harmlessness of the trial, the utter forgetting of the patient, the supreme interest in the prejudice. Vaccination is harmless and its protective effect easily demonstrated. To tap the chest with the finger is a very simple proceeding and the sounds elicited are easily recognized. It is not difficult, if so minded, for the nurse, midwife, and doctor to be clean, and thus test if puerperal fever is contagious. The physicians who clamored against railway travel because it would make passengers sick, giddy, or insane, and said if the foolish would build railways board fences must be raised above the height of the cars, — these physicians could have got on the cars and disproved their theory. The opposers of the theory of circulation of the blood might at least have tested the theory by pricking their fingers. The prejudice against rabies inoculation, the diphtheria antitoxin, the mosquito theory of malaria and yellow fever, etc., which resulted in untold deaths and delay of scientific progress, could have been easily tested. It is childishly simple to test the power of astigmatism to produce or cure migraine, and yet many prefer not to make the test.

There are probably not a half-dozen hospitals or ophthalmic clinics in the world fitted with a trial-frame or set of test-lenses that would enable even an expert refractionist to diagnose ametropia with the perfect accuracy which is necessary to cure morbid ocular reflexes. But those set to do refraction work in the public clinics are not expert. They are the students and learners. Hence nine tenths of the glasses prescribed in these institutions are not correct. Ophthalmic surgery and inflammatory diseases are all that interest, and these would be largely preventable by the refraction that is neglected and misdone.

Even in the institutions for the blind, it has been found that some of the inmates are not blind, and that their remnants of vision may be so vastly improved as to make these dependents self-supporting. In every school of the world at least 20 per cent of the pupils are suffering from ill-health due to imperfect eyes, and yet pedagogics, except infinitesimally and incipiently, does not know and does not care. The teachers and professors in preparatory schools, colleges, universities, technical and other schools, pay little or no attention to the ventilation of the rooms, or to the refraction of the eyes of their students. These are constantly breaking down in health, or in study, from migraine, etc., and the general scholarship is vastly depreciated because of the neglect of the eyes. An official and resident expert refractionist would make a university outdistance its rivals more than, *e. g.*, does all its "athletics."

In every asylum for the insane some patients are there because of bad eyes, — and if only a few are curable of the chronic disease, many could be relieved of the headaches, gastric, and other nutritional diseases which burden the attending physicians and the taxpayer. In one great institution for epileptics, a little experiment with glasses, imperfectly executed in many ways, showed a greater percentage of cures, a greater reduction in the number of seizures, than by all other methods of cure combined that had been tried in the institution. And yet the official report characterized the experiment as "disappointing" and sneered and misrepresented it. Epilepsy, it has been demonstrated, is in many cases due to ametropia; many cases could be prevented by proper glasses in the child, or during the early history of the case. In the chronic, severe, and hopeless cases it may not be always or even frequently curable. The conditions of the glass-treatment are exceptionally difficult to carry out, and often cannot be done at all, especially if conscience and sympathy are absent. The improved general health, freedom from headaches, etc., would make it at least a saving of money for the state to pay an expert resident oculist. This, apart from the humane consideration. Nobody can rightly estimate the number of degenerates, paupers, defectives, and dependents loaded upon the producers and taxpayers because reading, writing, sewing, handicrafts, etc., are impossible to a person with disqualifying astigmatism. Neglect of the fact greatly increases the tax-rate and makes the philanthropic miserable.

Why does the truant-boy exist, and why does he so often develop into the young criminal? If the majority of these, as Dr. Case of the Elmira Reformatory finds, have an ocular defect that makes vision impossible for any continued reading, writing, or handwork, does not the fact modify all penology? If the sewing-girl cannot possibly sew or do any such kind of eye-work, what alternative is often left her except crime? Sociology is very frequently another name for ophthalmology.

And if even to-day, in the city, the poor cannot be fitted with a simple device to make their lives happy and independent, how is it with the other half or three fourths of the people who live in small towns and in the country supplied only with the itinerant criminal spectacle-peddler? The farmers and their families now waste most of their evenings and their winters, and then the sociologist blames them for their vile country newspaper and their unprogressiveness.

Philosophers and thoughtless critics bewail the literary pessimism of the age. It is indeed a pitiable and a pitiful fact. In a time when comfort and possibility of education and of enjoyment have suddenly increased an hundredfold, why the strange phenomena of vastly increased skepticism, mental suffering, hopelessness, and melancholy? Who have set the fashion? Certain powerful, but in some respects morbid, literary geniuses. Who were they? Those almost without exception who were great sufferers from physical disease. Of what disease? Simply of "migraine." Without a thought of the class to which they may belong, make a list of the literary pessimists of the last century and another list of the optimists. The pessimistic or gloomy writers and artists were almost entirely great sufferers from eye-strain and from its result — migraine. They were, for instance, Nietzsche, the two Carlyles, de Maupassant, George Eliot, Wagner, Tchaikowsky, Chopin, Symonds, Tolstoi, Heine, Leopardi, Schopenhauer, Turner, Obermann, Thomson (the younger), Poe, and many others. Others that partially or wholly conquered the "migraine" of eye-strain by opium, or by renouncing ocular near-work, by walking, etc., are Mrs. Browning, DeQuincey, Coleridge, Beethoven, Parkman, Whittier, Margaret Fuller, Browning, Huxley, Spencer, Taine, Darwin, Lewes, Hugh Miller, Southey, etc.

The optimists — the cheerful, hopeful, encouraging, loving, and helpful ones — were, a few and at random, Goethe, Mozart, Verdi, Ruskin, Wordsworth, Renan, Châteaubriand, Hugo, Zola, Sainte-Beuve, George Sand, Emerson, Lowell, Longfellow, Kant, Scott, Brontë, Dumas, Voltaire, Gibbon, Macaulay, Mommsen, and a host of others.

In not one of the lives or writings of these last will you find a hint of eye-strain, or migraine, hardly even of ill-health. Note also that the pessimists are mostly atheistic and materialistic, while hardly one of the healthy optimists is so. One may also remember the tendency to despair and even suicide in those who suffered most from migraine. It is exactly so in private practice to-day. Pessimism and atheism are an expensive tax on the national vitality, a danger to the public health, a brake on the wheels of the progress of civilization. If we care naught for the personal and preventable sufferings of these great workers in humanity's cause, nothing for those of the literary and other laborers tremendously increased by the very nature of their tasks, we at least should consider the welfare of the generations that follow us. As the creation and perfection of vision has been the condition of past biologic evolution, so its normalization and the avoidance of its pathogenic results is one of our highest professional duties and ideals.

SECTION K—OTOLOGY AND LARYNGOLOGY

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(*Hall* 7, *September* 21, 10 *a. m.*)

CHAIRMAN: PROFESSOR WILLIAM C. GLASGOW, Washington University, St. Louis.
SPEAKER: SIR FELIX SEMON, C. V. O., Physician Extraordinary to His Majesty the King, London.
SECRETARY: DR. S. SPENCER, Allenhurst, N. J.

RELATIONS OF LARYNGOLOGY, RHINOLOGY, AND OTOLOGY WITH OTHER ARTS AND SCIENCES

BY SIR FELIX SEMON

[**Sir Felix Semon,** K.C.V.O., Physician Extraordinary to His Majesty King Edward VII of England. **b.** December 8, 1849, Danzig, Prussia. M.D. Berlin, 1873; German States Diploma, 1874; medical education at Berlin and Heidelberg Universities; F.R.C.P. London, 1885; M. 1876. Royal Prussian Professor; Post-graduate, Vienna, Paris, and London; Physician, Hospital for Diseases of the Throat, Golden Square, London, 1879–83; Physician, Diseases of the Throat, St. Thomas's Hospital, London, 1882–97; *ibid.* for National Hospital for Epilepsy and Paralysis, since 1887. President, Laryngological Section, British Medical Association, 1888 and 1895; Fellow of Royal Medical Clinical and Medical Societies, London; Member of Pathological and Neurological Societies, London; Hon. Fellow, Berlin, Munich, Italian, and Vienna Laryngological Societies; Corresponding Member of American Laryngological Association, Imperial and Royal Society of Physicians, Vienna, and Swedish Medical Societies; Knight Prussian Red Eagle (3d Class); German War Medal, 1870–71 (5 Clasps); Commander of Order of Isabella la Catolica; Grand Officier, Order of Medjidjie. **Author of** many books relating to diseases of the throat.]

WHEN Professor Newcomb's extremely flattering invitation reached me to deliver an address before the Section of Laryngology and Otology of the Congress of Arts and Science held in connection with this wonderful Exhibition, my first feeling was naturally one of sincere gratitude for the great honor done to me. This feeling was enhanced by the information contained in Professor Newcomb's letter that the invitation was extended on the nomination of a number of American representatives of medicine, whose names are household words on the other side of the Atlantic. I am deeply sensible, believe me, of the exceptional distinction thus conferred upon me, and my pleasure in accepting it is only marred by the consideration that I cannot pretend to be an aurist, and that the otological part of my task would no doubt have been infinitely better fulfilled by many European representatives of that branch. I dutifully mentioned this fact to the organizers of the Congress, but it was not considered an insurmountable obstacle to my undertaking the pleasant duty conferred upon me. Needless to say, I will do my best to do justice to the otological part of my address as well, but it will be intelligible to my hearers, and will, I trust, be pardoned by them that the lion's share of my remarks will be devoted to subjects rather of which I can speak from personal experience than to questions with which my work is less intimately connected.

If my first feeling on receiving your invitation was naturally and properly a sense of gratitude for the high distinction conferred upon me, this feeling was run very close by the sincere pleasure I experienced in thinking that I should have been selected to coöperate in a work so entirely sympathetic to me as is this great undertaking. It was stated in Professor Newcomb's invitation that the object of this Congress was "to discuss and set forth the uniformity and mutual relationship of the sciences, and thereby to overcome the lack of harmony and relation in the scattered special sciences of our day."

I do not know whether I was selected as having upheld throughout my scientific career this leading idea, but I can say without fear of contradiction — and in proof thereof, I may point to my literary work — that I have consciously and intentionally striven, wherever opportunity offered itself to me, to maintain the principle which animates the organization of this Congress.

I should not be a specialist if I did not firmly believe in the necessity of specialism in medicine. The immortal aphorism, "Life is short, art is long, technique is difficult," applies to-day with even greater force than when it was uttered two thousand years ago by the Father of Medicine. Whilst the span of life has since his time remained very much what it was then, his art has been and is making giant strides. Economical considerations stand in the way of indiscriminately prolonging the time of medical study, and more and more work has to be compressed within the span of the few years which serve to prepare the future medico for his professional life. No wonder, then, that it has become extremely difficult, nay, almost impossible, to equip our students so thoroughly that they can enter practical life with full knowledge of their craft in every branch of medical thought and work. Even the few who, endowed with good health and strength, with exceptional abilities, and with equally exceptional industry, succeed during their students' career in mastering all the details of current medicine will, with very rare exceptions, find it practically impossible, when once they have plunged into practice, to keep abreast of the rapid progress which is the signature of the times in which we live.

Under these circumstances division of labor has become a logical and unavoidable necessity. The old line of demarkation between internal medicine and surgery, to which, at a somewhat later period, gynecology and midwifery were added as independent branches, no longer suffices to carry on investigation and practice within their formerly strictly defined limits. Gradually one recognized specialty has developed after another, partly owing to the necessities of special training in a certain technique, partly because only men trained in that technique could promote further investigations.

The International Medical Congresses bear testimony to this unavoidable development of contemporaneous medicine. Their organizers desire nothing more than to limit the number of the Sections of the Congress, yet time after time is it found indispensable to create new sections. Thus, whereas at the International Medical Congress of Brussels in 1875 eight sections sufficed to carry on the work, which was truly representative of the state of scientific medicine at that time, that number had been more than doubled twenty-five years later, when no less than seventeen sections had to be formed at the International Medical Congress of Paris of 1900. Seeing the unexpected rise of so many branches formerly undreamed of within the memory of our own generation, he would be a bold man indeed who would dare to assert that the limit had been reached of further specialization of our science.

This progressive division of labor — the outcome, not of individual caprice, but of stern necessity — has certainly resulted, within the last fifty years, in greater progress of medical knowledge and power than has taken place at probably any corresponding period in the history of medicine. If we middle-aged men remember what medicine was when we entered upon our studies and see what it is to-day, and if we further reflect how much of all the progress achieved meanwhile is due to the labors of specialists, we have every reason I think to be grateful to the division of labor which has brought forth such splendid fruit.

But while this must be readily and ungrudgingly acknowledged, it cannot be denied that, as in almost every movement of a similar character, thus in this development of modern medicine there is one great and real danger, namely, the peril of over-specialization. Well do I remember, when I first selected a specialist's career, how incensed I was at the reproach then currently leveled at specialism, namely, that it engendered narrow-mindedness, and how ill-founded and unjust that reproach seemed to be to me. With longer experience and riper judgment I have learned that the danger of narrow-mindedness, accruing from too exclusive a devotion to specialism, is more than a mere phantom. Whether by natural turn of mind, or by want of steady connection with broader aspects of pathology, there is no gainsaying that the enthusiastic specialist is apt to see a local trouble everywhere, and to overlook disturbances of general health and other organs which in reality require the chief attention. The tendency which has become particularly marked during the last decade, namely, to confine research and discussion in special subjects to special societies and special journals, has materially increased that danger, the reality of which was foreseen nearly twenty years ago by my great teacher Virchow when in the address he gave at the jubilee meeting of the Berlin Medical Society on October 28, 1885, he spoke the memorable words, to which I have more than once referred, and which in verbatim translation are as follows:

"Amongst us has arisen the large army of specialists, and it would be useless, or at any rate fruitless, to oppose this development; but I think I ought to say here, and I hope to be sure of the consent of you all when I say it, that no specialty can flourish which separates itself completely from the general body of science; that no specialty can develop usefully and beneficially if it does not ever and ever again drink from the general fount, and if it does not remain in relationship with other specialties, so that we all help one another, and thereby preserve for science, at any rate, even if it should not be necessary for practice, that unity on which our position rests intrinsically, and, I may well say also, with regard to the outer world."

Under these circumstances it was certainly a happy thought to remind us again of the unity of Sciences and Arts, and to try thereby to overcome the lack of harmony and connection between the scattered special sciences of our day.

And I look upon it as a particularly characteristic sign of the times, and as a hopeful augury for the future, that the reminder should have come from the scientists of a country so eminently progressive as the United States of North America. If they, who are untrammeled by many of the traditions, formalities, and prejudices which so severely handicap us on the other side of the Atlantic, have found that it is high time to raise a warning word against the ever-increasing disruption of the unity of Science, surely this ought to make those pause, who with a light heart consider every further step on the road to so-called "independence" as a practical gain to specialism. If to-day by placing before you in rapid succession the intimate links which connect us with other arts and sciences I should succeed in convincing some of the more ardent protagonists of such independence, that laryngology, rhinology, and otology can only flourish and healthily progress by never for a moment losing sight of their close relationship with other often enough apparently remote branches of human thought, I conceive that I shall have contributed my mite towards the excellent object of this great Congress.

It is not a mere figure of speech when I say that the more I advanced in the preparation of this address, the more did I become impressed with the magnitude of my task and with the intimacy of unexpected or hardly-thought-of connections between laryngology, otology, and rhinology and other sciences and arts. These specialties have developed so much along characteristically independent lines that theoretically one might be inclined to think that they had comparatively little in common with other branches of medicine, let alone other sciences and arts.

Nothing could be better calculated to destroy such mischievous belief than the results of my inquiry. At every step during the preparation of this paper has it become clearer to me how much we owe to apparently remote lines of human thought, how much we have been and are benefited in our special work by progress made in other distant fields, and how much more good we may expect to accrue to us from the advances achieved in territories of human thought which a few years ago even the most fantastic visionary could not have brought into useful combination with our own occupation.

It will be my endeavor in this address to justify the foregoing statements by rapidly surveying the intimate connection of laryngology, rhinology, and otology — in addition to their relations with other branches of medicine — with physics, chemistry, mathematics, philosophy, history, biology, technology, and music, and I only regret that within the limit of time allotted to me it will be quite impossible to do full justice to my task.

I. *Physics*

(*a*) *Light.* Let us first take physics. The connections of that science with laryngology, rhinology, and otology are as manifold as they are interesting and important. The branches of medical science named have it in common that they deal with the investigation of the physiology and pathology of deep-seated cavities. Hence the question of their illumination for purposes of examination is of the greatest importance, and thus the chapter of physics dealing with the properties of light is a subject of immediate and pressing interest to us all. This applies with particular force to laryngology. Although of late, through the work of Kirstein, direct inspection of the larynx by means of depressing the tongue with suitable spatulas has been rendered feasible, this method of examination is only applicable in a certain fraction of cases, and examination of the larynx is still carried out universally by means of reflecting mirrors. The very foundation of laryngoscopy, as ordinarily practiced, depends upon the principle of physiological optics: that when rays of light fall upon a reflecting surface placed in a certain inclination towards the source of light, the angle of reflection is equal to the angle of incidence. Thus, if a small mirror be held at an angle of 45 degrees to the horizon just below the uvula, whilst a powerful beam of light is thrown horizontally into the throat of the person examined, the part just underneath the mirror, that is, the larynx, becomes illuminated by reflected light, and its image is in turn thrown back upon the mirror, and hence reflected into the eye of the observer, which is parallel with the rays thrown upon the reflecting surfaces. Exactly the same principle applies if, instead of the larynx, the nasopharyngeal cavity has to be examined, and the law of physiological optics just described is as all-important for posterior rhinoscopy as it is for laryngoscopy. But in order to obtain a really good image of either the larynx or of the nasopharyngeal cavity it is necessary that the light which is thrown upon the reflecting mirror should be a powerful one. Hence every progress which is made in concentrating and intensifying the light used for illumination of these parts is of the greatest interest for my branch of science. It sounds nowadays almost like a myth that the progress of laryngology in its infancy should have been retarded for almost half a year, and that Professor Türck of Vienna, who first utilized Manuel Garcia's epoch-making discovery of the laryngoscope for the investigation of pathological processes in the larynx, should have given up his studies for the time because the winter of 1857 in Vienna was a very dark one, and because sufficient light for illumination of the larynx could not be obtained from the direct rays of the sun. Yet such was actually the case, and it was only, as Morell Mackenzie has tersely stated, through Professor Czermak's substituting artificial light for the uncertain rays of the sun, and using the large ophthalmoscopic mirror of Reute for concentrating the luminous rays, that the initial difficulties were overcome. Thus already at this early stage lenses, another achievement of physiological optics, were employed to help our young science. Ever since, every improvement in the way of light has been a subject of the keenest interest for laryngology and rhinology. What progress have we made from the *Schusterkugel* — a large glass globe filled with water, originally employed by Türck and Stoerk — until we have been actually enabled to introduce a small electric lamp into the cavities of the body themselves to illuminate them properly for purposes of diagnosis and operation, or to throw light into the esophagus or the bronchial tubes, or to transilluminate the face for diagnostic purposes, as, for instance, for the diagnosis of disease of the maxillary antra or the frontal sinuses.

The employment of gas, recently followed by its new incandescent modification; the introduction of hydro-oxygen light, and, above all, that wonderful source of light, now in general use, the electric, have formed so many steps in the way of improving our powers in laryngology and rhinology. Quite recently the invention of the Nernst lamp has proved a great boon to us, enabling those who had been accustomed to the, if excellent, rather cumbersome use of hydro-oxygen light, to get illumination almost equally good at infinitely less trouble.

As if this had not been progress enough within the comparatively short span of a quarter of a century, Professor Roentgen's great discovery of the penetrating power of the ultra-violet rays, which now go by his name, has, at its very inception, been most happily utilized for the purposes of laryngology. When the extraordinary properties of the X-rays were made known I expressed a hope that by their help it might become possible to distinguish, owing to their different density, between benign and malignant growths. Although this hope has, unfortunately, not been realized so far, yet the medical attainments of these rays are surely wonderful. They enable us to discover the presence of metallic foreign bodies in the larynx, the lower air-passages, the nose and its accessory cavities. When it is doubtful whether paralysis of a vocal cord is due to the presence of an aneurism, or of a solid new growth in the chest pressing upon the pneumogastric or recurrent laryngeal nerves, the X-rays again come to our aid and help us to make a differential diagnosis. A further very ingenious application of the Roentgen rays has been made by Dr. Spiess of Frankfurt-am-Main, who has suggested that the delicate and by no means dangerless probing of the frontal sinus may be controlled and thereby rendered innocuous if during the act of introducing the probe the picture of the patient's head be thrown on the screen, the operator being thus enabled to see whether the instrument is really on the right way into the frontal sinus.

Who will be bold enough to say that with such discoveries the resources of physics have been exhausted, and that possibly at some near future some other even more powerful source of light may not be introduced? Those who are unwise enough to believe in the finality of scientific progress need simply be reminded of the possibilities, quite recently introduced through the discovery of radium with its as yet imperfectly known properties.

Before leaving the subject of light I must refer to some other methods in which that branch of physics has been rendered useful to our specialties.

The Microscope. The first of these is the use of the microscope. On this point I need say but little. The enormous value of the microscope in medicine is so universally recognized that it would mean carrying coals to Newcastle if I were to enlarge upon it. Our specialties have been benefited as much in the understanding of the finer processes of normal and pathological anatomy of the throat, nose, and ear, as any other branch of our mother science. It suffices to mention the help which the microscope gives us in the differential diagnosis between benign and malignant growths, in the recognition of tuberculous and diphtheritic affections, in the differentiation of septic disease in general, to show the truth of my statement.

Stroboscopy. Another, though much more restricted application of light for the use of laryngology, is stroboscopy. By an ingenious modification of the stroboscope, consisting of two rotatory disks, the one perforated, whilst on the other figures are drawn, which are inspected through the perforation of the first disk, the late Professor Oertel has succeeded in constructing an apparatus by means of which the oscillation of the vocal cords can be accurately observed. Very interesting observations on the action of the vocal cords during singing have been made with the aid of this apparatus, as an example of which I may only mention that, according to Oertel, "the sounds of the chest register are produced by oscillation of the vocal cords in their entire length and breadth, whilst the sounds of the falsetto register are caused by the longitudinal division of the surfaces of the vocal cords into aliquot parts, nodules being at the same time formed on them."

Photography. A further method to be mentioned in this connection is photography. I need not say that photographic reproduction of preparations illustrating the normal and pathological anatomy of the ear, the nose, and the throat is no exclusive property of laryngology, rhinology, or otology, but a special interest connects the former of these sciences with photography, inasmuch as by the aid of this method a number of most interesting observations have been made on the physiology of the larynx during the act of singing. The method has proved particularly useful in showing the absurdity of the preconceived ideas of some teachers of singing as to the extent of the individual registers. It has fully corroborated the views held by those most competent to speak as to the enormous variety in producing the singing voice, even in persons whose voices belong to one and the same category. The pioneer in this fascinating territory has been an American, my friend Dr. French of Brooklyn, and to his enthusiasm and perseverance have been due the first reliable results of this most promising method of physiological investigation. Further studies in this direction have been made by Dr. Musehold and Professor E. Meyer of Berlin. The last-named gentleman has just, in coöperation with the celebrated mechanician, Zeiss of Jena, constructed a very ingenious apparatus for demonstrating and photographing the larynx; but having seen the photographs obtained by its use, I am bound to say that the work done by Dr. French has not been so far surpassed.

Stereoscopy. Finally, in connection with light, I must not omit to mention the ingenious application of stereoscopy for purposes of medical teaching made by my friend Dr. Watson Williams of Clifton in the wonderful atlas which accompanies the second edition of his work on Diseases of the Upper Respiratory Tract. It being often extremely difficult to obtain, for teaching purposes, really illustrative preparations of the accessory cavities of the nose, the employment of the principle of stereoscopy in order to substitute photographs, the plasticity of which truly rivals life, may fairly be described as a triumph in utilizing for our special purposes the achievement of an apparently very remote science.

The mention of electricity, the X-rays, and radium naturally brings to our minds the fact that the chapter on light is of interest to laryngologists and rhinologists, not from the point of view of the question of illumination alone. We are privileged to live in a time when the great healing powers of light have been discovered and are utilized in a class of cases in which there is much need for addition to our therapeutic armory. The light of the sun, the electric light, the ultra-violet rays, and the emanations of radium are nowadays utilized with much success for the treatment of lupus, of rodent ulcer, and of some of the more superficial forms of malignant disease; and it may fairly be hoped that further progress may be made in the treatment of these cruel affections even when they occur in parts not easily accessible to the effects of the various rays.

(*b*) *Sound.* Whilst the chapter of physics dealing with light and its powers is, as I have just endeavored to show, of the very highest importance for laryngology and rhinology, the chapter on sound holds an equally high position with regard to otology. I need not elaborate that a science which is prominently concerned in dealing with the troubles of hearing is inseparably connected with the physics of sound. Thus the tuning-fork is one of the most indispensable weapons of the aurist, and the question whether the sounds caused by its vibrations are more easily perceived by aërial or by bone conduction is of the highest diagnostic importance in a large number of ear affections. In the same category may be mentioned Galton's whistle for the testing of the hearing of high notes. Again, the question of the capacity for the perception of tune; the difference in perception according to whether the mouth is closed or open; interference phenomena; the estimation of the hearing capacity for speech; the audibility of different sounds; the differential diagnosis between affections of the sound-conducting and sound-perceiving apparatus — are all questions intimately connected with the physics of sound, and it might be said without exaggeration that otology without constant close relationship with physics is an impossibility.

The Phonograph. Speaking of sound, the phonograph, an invention due to American genius, must not be forgotten, although its possibilities in connection with our triad are still in their infancy. I may remind my hearers that very shortly after its introduction Dr. Mount Bleyer of New York, Dr. Lichtwitz of Bordeaux, and I, independently of one another, conceived the idea of utilizing its recording powers for the purposes of instruction. One does not always have a case of whooping-cough at hand if one lectures on that disease, and although it be easy and true enough to say that the peculiar cough connected with that disease was so characteristic that any one who had ever heard it would never forget it, it is not so easy to demonstrate practically in what the characteristics of which one speaks consist. Here the phonograph comes to one's aid: let the child afflicted with that disagreeable affection cough a few times into the apparatus, and turn it on, when you have to lecture on whooping-cough and have no illustrative case near. The whoop will come out true enough!

It need not be said that the investigation of different forms of cough and hoarseness is only one of the modes in which the discriminating powers of the recording mechanism of the phonograph could be utilized. Attempts have already been made by Dupont to investigate with its help modifications of speech in different forms of delirium, paralysis, multiple sclerosis, etc. More recently Flatau of Berlin has studied the various forms of vocal disturbances by means of Edison's phonograph, and has also utilized it for investigation of the finer mechanism of the singing voice. With further perfection of the apparatus it may justly be hoped that yet more valuable results may be obtained than those so far achieved, although even now they are anything but a negligible quantity.

The Sensitive Flame. Finally, in this connection it should be mentioned that König's sensitive flame has been utilized for the registration of sound-waves produced by the human voice. The apparatus consists of a rapidly rotating cube, the four lateral sides of which are formed by mirrors, and of a membrane in the side of a gas-chamber, connected with which is a small sensitive gas-flame. If a note be sung on to the membrane the flame bobs up and down and the waves seen on the mirrors are not simply up-and-down ones, but the primary large waves are complicated by smaller ones on their surface. The richer the voice the more numerous are the overtones of the harmonics represented on the reflecting sides of the rotating cube. (Halliburton).

(c) *Electricity.* The enormous progress of the science of electricity made within our generation has had the most useful effects upon the diagnostic and therapeutic powers of laryngology, rhinology, and otology. In fact, there are probably but few collateral sciences in which our specialty is so keenly interested and the progress of which so greatly benefits us as electricity in all its different forms. It has already been stated that the illuminating power of the electric light is being utilized not only for ordinary but also for trans-illumination of the cavities of the head and neck, and for the inspection of the lower air- and food-tubes. The constant and faradic currents are of the greatest help to us both in diagnosis and in treatment. By means of the reaction of degeneration we are enabled to decide whether paralysis occurring in the mouth, the pharynx, or the larynx is of central or of peripheral origin. By employing both forms of current we succeed in many cases in curing paralytic disorders, more particularly when they are of functional character.

Again, electricity in the form of the galvano-cautery is of practically daily use in the hands of the laryngologist and rhinologist. It has superseded the employment of most other forms of caustics, and few laryngologists nowadays would care to be without it.

Yet another form of employment of electric force, namely, electrolysis is highly extolled by some devoted adherents who utilize it for the treatment of such troublesome affections as ozena, naso-pharyngeal fibromata, reduction of irregularities of the nasal septum, etc. It must, however, be confessed that this method has never met with general adoption by the bulk of laryngologists.

Finally, in recent times the motor power of electricity has been largely used, and I do not think anywhere more than in the United States, as the driving force of such instruments as trephines, saws, drills, particularly in nasal surgery and electro-motor masseurs in aural therapeutics. If the method has not yet met with general acceptance in Europe it is, I think, more from want of acquaintance with it than from any other cause, and I feel confident that the more general the domestic use of electricity shall become, the greater rôle will the electro-motor play in our instrumentarium.

Even as it is now, however, the rapid sketch I have just drawn will suffice, I trust, to show the enormous importance of this branch of physics for our special field of research.

II. *Chemistry*

Whilst it cannot be said that chemistry, apart from its general relations with medicine, is so closely connected in its various branches with laryngology, rhinology, and otology as physics, yet there are points enough of very great and immediate importance which link these two sciences together.

In the first place, synthetic chemistry gains every day in importance for us by enriching us with new and important pharmaceutical preparations. Need I remind you of orthoform, anesthesine, adrenalin, iodoform, sozoiodol, peroxide of hydrogen — to mention a few only of the large number of new remedies which form, so to say, our present stock-in-trade, and for the introduction of which we are indebted to synthetic chemistry? Every day increases our power of doing good, due to the progress made in this collateral science, and we are therefore accustomed to watch constantly nowadays for further help in our therapeutical powers from that source.

Skeptics, it is true, may say with some show of reason that we had lately had and were still having a little too much of a good thing in the shape of new remedies, but I the more gladly leave that undecided, as chemistry comes to our aid not only with regard to therapeutics but also to diagnosis. It is mostly by means of the different chemical reactions of cerebro-spinal fluid, and of the ordinary serous secretion met with in vasomotor affections of the nose that we can differentiate between these two affections.

Finally, although this may perhaps be called "music of the future," I myself look forward to the day when further progress in physiological chemistry will enable us to recognize subtle differences in the composition of nerves and muscles. Should that hope be realized, physiological chemistry will perhaps enable us to solve that great problem, which for the last twenty-five years has occupied the minds of so many of us — namely, the cause of the greater proclivity of the abductor fibers of the recurrent laryngeal nerve, and the muscles which they supply, to succumb sooner than the adductors, or even exclusively in cases of organic disease of the roots and trunks of the motor laryngeal nerves.

III. *Mathematics, including Statistics*

Occasionally the resources of mathematics have to be laid under contribution by our specialties. Thus, for instance, it was necessary when I studied some years ago the position of the vocal cords in quiet respiration in man, to correct, when using graduated laryngeal mirrors, the considerable difference between the actual and the apparent length of the distance measured. This difference could be accurately expressed by a mathematical formula.

Similarly, in a recent paper on the aërodynamics of the respiratory passages, Dr. Gevers of Leuven measures mathematically the permeability of the nasal chambers. On the whole,. however, it must be confessed that the connection between pure mathematics and laryngology, otology, and rhinology is only a distant one.

But matters become very different if we look upon the science of statistics as a method of applied mathematics, and consider its employment in our literary work under the present heading.

More and more frequently of late years has the statistical method not merely been laid under contribution, but been allowed to have a decisive vote in questions of the greatest importance for laryngology, otology, and rhinology. It may therefore not be out of place to express on this occasion a devout hope that those who employ this method for the decision of controversial points in our own science, should make themselves first acquainted with the general principles of the method itself. The non-observance of this precaution has led in more than one instance not only to fallacious scientific conclusions but to deplorable practical results.

I will illustrate this by one example only.

In no chapter within the territory of our own specialties has the statistical method of late years been more frequently used than in that of cancer of the larynx. As a matter of fact, the usefulness or otherwise of the individual operations now practiced for the cure of that terrible disease is judged by most surgeons exclusively on the basis of statistics recording the results of various forms of operation. Unfortunately, however, a good many of those who have compiled such statistics have done so in a most empirical manner. They have simply registered under one and the same heading all operations of one and the same type ever performed without taking into consideration such indispensable distinctions as:

1. The period of our knowledge at which each of these operations was performed.
2. The individual and enormously different conditions present in each of the cases which were subjected to one and the same operation.
3. The progress of the technique of these operations as they gradually developed.

The outcome of this, as will be clear to everybody who has paid any attention to the principle of statistics, has naturally been lamentable. Most valuable forms of operation, such as thyrotomy, have been and unfortunately still are persistently discredited, because some compilers of these statistics will not or cannot see that a thyrotomy performed, say, in 1870, was a thing as different as heaven and earth from a thyrotomy performed in 1904 under altogether different conditions of diagnosis and technique. They accordingly put together all thyrotomies ever performed, without taking these all-important differences into consideration, and calmly proceed to register the net result. The natural outcome of such directly misleading statistics has been that the true value of thyrotomy in suitable cases has not nearly universally enough been recognized at the present moment, and those who have practiced it with excellent results in really suitable cases during the last fifteen years have even at this hour of the day to carry on an uphill fight against those who put their faith blindly in the unsatisfactory sort of statistics just described. The hope may therefore be justly reiterated on this occasion that every medical man who wishes to approach a medical question from the statistical point of view should make himself thoroughly acquainted with the standards of his measurements before applying the latter to the question which he intends to study.

IV. *Meteorology and Climatology*

A few words only are requisite at the present state of our knowledge with regard to the connection between meteorology and laryngo-otology. The more we learn of the influence which climatic and meteorological conditions exercise upon certain diseases, the more necessary does it become to study these conditions in order to benefit our patients, and to avoid serious mistakes in sending them to localities which, however suitable in other affections, are not adapted for their particular case. This general rule applied to our specialties comes particularly into force with regard to laryngeal tuberculosis and to middle-ear catarrh. With regard to the former, I need simply mention that at present the opinions as to the suitability or otherwise of high altitudes in cases of laryngeal complications of pulmonary tuberculosis are extremely divided; with regard to middle-ear catarrh, one sees it frequently stated that seaside places exercise a distinctly unfavorable influence upon them. But the relation of meteorology and climatology to our branches is certainly a wider one than indicated in the foregoing illustrations, and well deserves — and will no doubt receive — further attention.

V. *Philosophy, Logic, History, and Literature*

Of the connections of philosophy, logic, history, and literature with laryngology and otology I wish to say a few words jointly, because their relations to our specialties are similar in kind. They are not of that palpable and, if I may say so, tangential character, as those of physics, chemistry, and mathematics, and of the other branches of human intellectual activity to be touched upon hereafter, in that it is impossible to name individual distinct points in which their achievements touch equally distinct and individual points of specific interest for us. But, although more subtle, their relations with the higher aspects of our work are no less intimate, and additionally, if I may say so, are all-pervading. The specialist who is endowed with a philosophical turn of mind will look upon his own work and upon the interests of his specialty from a much broader point of view than the man whose horizon is obscured by the limited and more or less narrow-minded doctrines of one individual school of thought. He will not be swayed by the fashionable currents of the moment, and will be consoled when he sees that not only the public but many within the ranks of his own confraternity periodically lose their heads over the latest sensational development, destined in the opinion of its creator and its disciples to bring about in our own times the millennium, by the remembrance of Ben Akiba's immortal dictum:

Alles schon dagewesen (nothing new under the sun),

and by the reflection that in all probability in a very few years the same faithful ones will bow down and worship another golden calf. The man who has learned to think logically will not, when he writes a paper, be caught, in glaring self-contradictions, and will carry, when following a chain of thoughts, that chain to its only possible conclusion. The author who does not confine his literary studies to the reading of exclusively medical productions, who has been brought up with a knowledge of all that is good in the literary productions of former as well as of our own times, and who has a warm heart for poetical and literary beauties in the literature of all nations, will make his own work attractive to readers, and will know how to give clear expression even to abstruse scientific questions. And, in conclusion, the laryngologist and otologist, who knows something of history in general and of the history of the development of his own specialty in particular, will have an infinitely higher standard of comparison of the achievements of the present day with those of our predecessors than the man for whom all that has been published ten years ago is merely "ancient history" not worth reading. Above all, he will have learned from the lessons of the past the one great truth that, however important a discovery he may imagine he has made, it behoves him to be modest in the face of what has been done before him.

It is extremely tempting to illustrate what I have just said by reference to the writings of some of our *confrères*, whose scientific productions are distinguished by literary charm, by limpidness of expression, by inexorable logic of thought, and by profound knowledge of the history and literature of other subjects, but apart from the question of the length of this address, which hangs over me like the sword of Damocles, the task, although enticing, would be somewhat invidious. Still I hope that nobody will grudge it if, before leaving this part of my task, I refer with admiration to the work done by two American specialists, and illustrating the truth of what I have just said, namely, the excellent historical and literary researches of Dr. John Mackenzie of Baltimore, which give quite a special *cachet* to several of his papers, and the recent magnificent medical history of laryngology and rhinology by Dr. Jonathan Wright, which, owing to a most unusual combination of all the philosophical, literary, and historical qualities of which I have spoken will, I feel sure, ever remain a classic in the literature of our specialties.

VI. *Technology*

A few words must suffice to remind you of the great importance of every technological progress for those whose special practice lies in the treatment of throat, nose, and ear diseases. From year to year these specialties tend more and more to become branches of surgery, and the question of their surgical equipment therefore is constantly with us. Most of our instruments are no doubt invented by specialists themselves, but in not a few cases we are only able to give a leading idea to the instrument-maker, and the success or otherwise of our idea depends upon the constructive talent of the latter. Nor is it rare that patients themselves devise improvements of existing instruments and apparatus. Thus, for instance, the most ingenious and at the same time simplest speaking-apparatus which I have ever seen used by patients condemned to wear for a time or forever a tracheal cannula was constructed by a watchmaker who had the misfortune himself to belong to the class of patients in question. A glance at the innumerable "modifications" of instruments now in general use recommended in the catalogues of various instrument-makers shows the intimacy and importance of our relations with technology, and I desire in conclusion of this reference only to remind you of the quiet revolution that has been going on in our tools of late years in proportion to the greatly increased importance of aseptic surgery, and in the course of which it has become the aim to have all our instruments fashioned out of metal, and to banish wood entirely.

VII. *Music*

Next we come to a most fascinating subject — the relation of the noble art of music to laryngo-rhino-otology. Of the intimacy of this relation there can be no possible doubt; without what is called a "musical ear" music is an impossibility altogether; without the possession of a healthy larynx, singing cannot be thought of. When I speak of a "musical ear" I mean, of course, the control exercised by the ear over the technique of executants; that music in its highest forms is completely, or at any rate nearly, independent of the power of hearing has been shown by nothing more conclusively than by the case of deaf composers, whose "inner voice," to speak with Robert Schumann, elevated them beyond the apparently indispensable faculty of hearing. Beethoven was deaf when he wrote the Ninth Symphony, and nothing more pathetic surely can be imagined than, when his audience after its first performance rose to an indescribable pitch of enthusiasm, one of the singers had to turn the deaf Maestro round in his chair to see

— what, alas, he could hear no longer — the applause with which the public of Vienna greeted this probably the greatest musical composition of all times. But even in this exceptional case the close relationship of the art of music with the physical faculties of sound and hearing is characteristically illustrated. If the musical ear had come to the great composer's help in the final chorus, I cannot imagine that he would have written the soprano parts as he has done — too high to be reached without great effort by the voice and not pleasing in its effect to the tympanum of the ordinary listener.

As to the connection of laryngology with singing, no more significant testimony could surely be adduced than the fact that the laryngoscope, upon which modern laryngology is based, has been the invention, not of a medical man but of a singer, the venerable Señor Manuel Garcia, who has been spared by a merciful Providence to live in undimmed possession of all his mental and physical powers to the patriarchal age of 100, and whose 100th birthday we hope (D. V.) to celebrate in March of next year. The auspicious event will coincide, I may remark, with the jubilee of laryngology, his epoch-making paper, entitled *Physiological Observations on the Human Voice,* which he submitted to the Royal Society of London in 1854, having been published in the *Proceedings* of that Society (vol. XII, no. 13) in 1855. Garcia was led to his discovery by the natural desire of an intelligent singer to study the physiological properties of that most wonderful of all instruments, the human voice, by direct inspection of its constituent parts during the act of singing. Ever since manifold endeavors have been made to let the art of singing profit by the revelations given by the laryngoscope. Candor, however, compels me to say that these efforts have hitherto been less successful than one might naturally have expected. Pretensions have been, and are being made as to the claim of the laryngoscope to lay down the law concerning most intricate questions arising in the production of the singing voice; but as I have stated on a previous occasion, there exists no "superior wisdom" based upon laryngoscopic observations with regard to the teaching of singing. Now, as in bygone days, the teacher who founds his instruction upon the classical traditions of the art of singing and who individualizes in every case intrusted to his care will certainly be more successful than the theorist who, starting from preconceived notions the correctness of which is anything but proven, forces the natural mechanism of his pupils' voices into his unbending formula and thereby in not a few instances ruins them.

This warning is of course not intended in any way to deter both laryngologists and singing-masters from joining forces in determining questions regarding the physiology of the voice, and recent work such as that of Holbrook Curtis, Flatau, Bukofzer, and Imhofer shows how valuable the laryngologist's aid may be in assisting the task of the teacher of singing in such questions as, for example, the method of intonation — a point in which science and art very nearly touch one another. Future anatomical and physiological researches will have to solve the fascinating questions of the mutual interdependency of the centres and paths of audition and sound in the brain. The data at present at our disposal are not sufficient fully to understand through what kind of afferent and efferent fibers impressions are conveyed to and from these centres; how they are changed into volitional impulses, and how they produce the desired note of the voice.

For the purposes of this address the foregoing short remarks will, I trust, suffice to show that no better illustration of the mutual relationship of most various arts and sciences could be imagined than in the territory of music, and more particularly of singing. That noble art is inseparably interwoven with laryngology, otology, rhinology, — for the accessory cavities of the nose are serving as resonators for the sounds produced in the larynx, — anatomy, physiology, and physics.

VIII. *Biology*

If we consider the relation of our branches to biology — excluding from the generic term thus used human anatomy and physiology — the same remark applies to their connection which I have just used when speaking of the relation of music to our specialties; more might be expected from the future than has been achieved in the past. No doubt the study of comparative anatomy and physiology, particularly the developmental part of these sciences, has been very useful in making us understand the origin, the gradual development, and final composition of the complicated organs with which we have to deal, and in not a few questions — more particularly in those relating to the nervous mechanism of the larynx — the lessons derived from experimental physiology have already been of the greatest importance in helping to solve the difficult problems with which we have to deal. Still, I am in no fear of contradiction when I say that a great deal more may be expected for the elucidation of many difficult questions with which we are confronted in laryngo-oto-rhinology from further biological studies.

IX. *Medicine*

Finally — and though last not least — I have to discuss the relations of laryngo-oto-rhinology with other branches of our great mother science, Medicine. The subject is one so large that, to do it justice, not one but a course of lectures would be required. At every step the specialist whose mind is open is reminded of the close connection of his limited field of achievement with other branches of medical art and science.

Anatomy, Physiology, Pathology. He can do no good without an intimate knowledge of the anatomy of the organs intrusted to his care and of their anatomical relations to adjoining and even more distant parts. In order to understand morbid conditions of the nose, throat, and ear, he must be thoroughly acquainted with the action of these organs in health, in other words, with their physiology. Wherever clinical observation is insufficient or at fault, he can appeal to no better helpmate than to the researches of pathological anatomy, and it may be truly stated that the conviction of this intimate association with the three sciences named is becoming more and more alive in our minds. We no longer leave the investigation of anatomical, physiological, and pathological problems pertaining to our specialties exclusively in the hands of professors of these branches; a large number of very valuable contributions towards the elucidation of such problems has been made of late years by members of our own specialties, and in not an inconsiderable number of instances the coöperation between laryngologists, rhinologists, and otologists with pure anatomists, physiologists, and pathologists has been productive of most valuable scientific results.

It suffices to mention the anatomical work of B. Fraenkel and his school, of Broeckaert, Onodi, Paul Heymann, Elsberg, Carl Seiler, Körner, Jelenffy, Killian, Politzer, Gruber, Urban, Pritchard, Tilley, Logan Turner, Kanthack, Seifert, Siebenmann, Gouguenheim, and Lermoyez; the physiological researches of Schech, Grabower, H. Krause, Katzenstein, Klemperer, Fraenkel, Hooper, Bryson Delavan, Frank Donaldson, jun., Desvernine, Réthi, Hajek, Zwaardemaker, Greville MacDonald; the pathological studies of Heinze, Grünwald, Kuttner, Seifert, Kahn, Heryng, and Butlin, and the joint work of B. Fraenkel and Gad, of Bowditch and Donaldson, of von Mering and Zuntz, of Mikulicz and Michelson, to which I hope I may add the researches undertaken by Victor Horsley and myself — to show that the above statements are not mere assertions, but based upon solid facts. On the other hand we gratefully recognize the most important help that has come of late years to the aid of laryngological knowledge from such distinguished anatomists, physiologists, and pathologists as Luschka, Sappey, Zuckerkandl, Exner, Hermann Munk, Richard Ewald, Risien Russell, Bechterew, and others. And yet these are, I particularly wish to state, a few names only taken at random from one's recollection of those who have enormously improved our knowledge of the anatomy, physiology, and morbid histology of the throat, nose, and ear, within the last twenty years.

Bacteriology. From pathological anatomy in general, there is but one step to the latest development of that science, bacteriology. Here again the close relationship of our specialties to this new science is evident everywhere. We learn from the bacteriological examination of the sputum in cases in which the clinical examination of the nose, pharynx, larynx, or ear leaves it doubtful whether we have to do with tuberculosis the true nature of the process that engages our attention; we differentiate with the help of bacteriological examination between true diphtheria, Vincent's angina, and other forms of septic inflammations of the cavities of the mouth and throat; the employment of antitoxin enables us to deal infinitely more effectively than at any previous state of our knowledge with that scourge of humanity, diphtheria; we ascertain in those terrible although fortunately rare cases, which I have grouped together under the name of "Acute Septic Inflammations of the Throat and Neck," the nature of the particular pathogenic microörganism that is causing the disease in a given case, and although as yet by no means masters of the situation, we succeed in a certain number of these cases, namely, in those in which the streptococcus is producing the septic inflammation in warding off by the employment of antistreptococcus serum the otherwise unavoidable fatal issue. As a matter of fact, an almost unlimited vista of further progress has dawned for our specialties in a number of previously most intractable affections from the rise and progress of bacteriology.

Internal Medicine. On the connection of laryngology, rhinology, and otology with internal medicine it is practically unnecessary to dwell. Whilst there is, needless to say, a number of local diseases of these organs strictly limited to them, in another large and important number the affection for which the aid of the specialist is sought is only part and parcel of a systemic disease, and as I have endeavored to show on another occasion, it would seem high time that not only the public, which has rushed to the conclusion that all affections of the throat, nose, and ear ought to be treated locally, but also some enthusiastic specialists should come to understand that in such cases not so much local as constitutional treatment is indicated. There are numbers of cases of general anemia, of periodical disturbance of the circulation, of general plethora, of nervous irritability, of gout, in which, without any actual changes existing in the throat, nose, or ear, unpleasant sensations are experienced in these parts, which can only be effectually treated by attending to the systemic conditions which underlie these local sensations. On the other hand, actual organic lesions occurring in these parts often enough are of the greatest importance for the diagnosis and proper treatment of grave general diseases. To give but a few examples: paralysis of one vocal cord may for a long time be the only actual sign discoverable, with the means at present at our command, of aneurism of the aorta, or of other mediastinal tumors, of affections in the posterior cavity of the skull, of pleuritic thickening of the apex of the right lung, of cancer of the gullet, and a host of other grave organic affections; certain laryngoscopic appearances may enable us to diagnose the existence of pulmonary tuberculosis at a time when all other signs fail; Killian's bronchoscopy, one of the most valuable modern additions to our diagnostic and therapeutic equipment, permits us to remove foreign bodies from the interior of even smaller bronchial tubes — chronic obstruction of the nose undoubtedly exercises a very unfavorable influence upon the general health, a fact which is most clearly demonstrated by the surprising improvement of well-being which follows removal of adenoid vegetations in much-developed cases — a cerebral abscess is nowadays known to be much more frequently due than was suspected only a few years ago to diseases of the middle ear and mastoid process, and has become infinitely more accessible to treatment than one could venture to hope in previous times. I may further remind you of the frequency with which the throat, nose, and ear are affected in infectious diseases, such as measles, scarlet fever, small-pox, typhoid, and influenza; again, of the manifestations of gout, rheumatism, and syphilis in these parts, and this list could be easily extended. The above examples, however, will suffice, I hope, to show the intimacy of the relations between our specialties and internal medicine.

Surgery. If I just said that it was almost superfluous to insist on the intimacy of our relations with internal medicine, this certainly applies in an even higher degree to their connection with surgery, for indeed they are daily becoming more and more branches of surgery itself. I have on another occasion stated my own conviction that it is in the nature of things, when a part of the human body has been made more accessible to eye and hand by the progress of science, that the treatment of affections of that part should gradually change from the medical to the surgical side. So much has this been the case of late with regard to the development of laryngology, otology, and rhinology, that if there be any danger in its further progress it would certainly not be in the direction of underrating but of over-emphasizing the idea that the existence of an affection of the ear, nose, and throat must be invariably associated with the idea of surgical interference. However, this is a subject on which I have no wish to dwell again on this occasion, and I much rather recognize the brilliant progress made of late years — and I may proudly add mostly by specialists — in the surgical treatment of the early stages of laryngeal cancer by thyrotomy, of affections of the accessory cavities, and of deviations of the septum of the nose in the radical treatment of mastoid disease, and in the removal of foreign bodies from the bronchi and esophagus. All these achievements belong to the veritable triumphs of contemporaneous surgery.

Children's Diseases. The large proportion of children seen in the out-patients' room and at the private consultations of specialists for throat, nose, and ear affections bears eloquent testimony to the close associations between diseases peculiar to childhood and affections of the auditory and upper respiratory tract. Here, of course, in the first place, adenoid vegetations and their far-reaching influence upon general development have to be mentioned, an influence of which it may only be devoutly hoped that it should not be overstated. But there are additionally the infectious diseases of childhood, in the course of which complications on the part of the ears, the throat, and the nose play a large rôle. It is pleasant to note how much more attention is paid to the condition of the upper respiratory tract and the ears of children by Government and public health officers than was the case only a few years ago, and to read of the increased frequency of the examination of school-children with regard to their hearing and breathing powers in different countries of the world. That is certainly the proper way to promote the health of the community.

Ophthalmology. Whilst in this country for a number of years the specialistic treatment of affections of the eye, throat, ear, and nose has frequently been combined on one hand, both in private practice and in hospitals, it is only comparatively recently that attention has been more prominently directed towards the close association of affections of the eyes and nose. The pioneer in this direction has undoubtedly been Dr. Ziem of Danzig. But much has been learned regarding the importance of this connection since he published his first paper about twenty years ago. The reader who has not himself worked on the subject will be surprised to learn from the recent brilliant contribution to this question from the pen of Professor Schmiegelow of Copenhagen how much more has been done in this field since Ziem's first investigations were published and how much more remains to be done.

Dermatology and Syphilitic Diseases. Here again the close connection between manifestations on the external integument and similar ones on the mucous membranes is a well-established fact. The chapter on syphilis of the throat, nose, and ear is one of the most important in our field, and the possibility of syphilis must be always kept in view in the event of our meeting with any obscure affection. On the other hand, eruptions on the mucous membranes of the pharynx, nose, and larynx not only accompany in a number of cases analogous skin affections, but may precede such external manifestations or even remain for a long time limited to the mucous coverings. Thus lupus, herpes, pemphigus, lichen, and a host of other eruptions sometimes occur first in the parts intrusted to our care and may baffle the specialist whose knowledge of skin diseases is limited.

Neurology and Mental Diseases. When discussing the relations of our specialties with internal medicine I have already incidentally mentioned the significance of laryngeal paralysis for the diagnosis of some of the gravest intrathoracic diseases. It is, however, not only in connection with these but with numerous affections of the central nervous system that laryngology is of the greatest importance for neurology. The discovery of a laryngeal paralysis may be for a long time the first sign of the existence of organic central nervous disease, and in no affection is this more clearly shown than in tabes dorsalis. Again, neuroses of the olfactory nerve not rarely accompany important intracranial affections. Thus anosmia may occur in hysteria, basilar meningitis, and locomotor ataxy, and parosmia may be met with in hysteria, epilepsy, hypochondriasis, or may precede mental disturbances of an even graver character. Affections of the inner ear and of the auditory nerve occur in many diseases of the central nervous system. Auditory hallucinations, such as the hearing of voices, may accompany or even usher in different forms of insanity, and symptoms of Menière's disease probably come as often under the observation of the neurologist as of that of the aurist.

I forbear from entering upon a further enumeration of the branches of medicine with which our specialties have points of interest in common. My list is by no means exhausted, and I may as a proof of this remind you of the connection between them and dentistry, the point of contact being the affections of the antrum of Highmore, but in truth it may be said that there is hardly one single branch of medicine which does not occasionally come into touch with laryngological, rhinological, or otological interests.

In conclusion I should have liked to dwell upon the relations of the three specialties to one another, a question on which I hold views of my own. But apart from the need of keeping my own observations within the limits of the time specified, it would be out of place to introduce controversial matters into an address of this kind; and further I have on more than one previous occasion stated my opinions on this most important topic as clearly as I could.

And now, gentlemen, that I am at the end of my task, let me say that nobody could be more painfully conscious than I am how incompletely I have fulfilled it. I had intended to bring before you a picture full of life, and on looking back I have to confess to myself that I have offered you little more than a framework the details of which must be filled by your own knowledge and imagination. I had hoped to give you chapter and verse for every statement I have made, and I see that my paper is little more than a sort of catalogue under the headings of which only indications but no elaborations could be given.

But whilst unreservedly recognizing these shortcomings, I trust I may justly plead that the subject confided to me is one of such magnitude that within the limit of time necessarily imposed upon me it was well-nigh impossible to do full justice to it. Yet incomplete as my exposition has been, I venture to hope that it has illustrated by the demonstration of the intimate connection of laryngology, otology, and rhinology with human activity in so many other branches of Art and Science, the truth of Goethe's immortal dictum:

> Truly the fabric of mental fleece
> Resembles a weaver's masterpiece,
> Where a thousand threads one treadle throws,
> Where fly the shuttles hither and thither,
> Unseen the threads are knit together,
> And an infinite combination grows;

and that it has more than justified the warning words of my great teacher Virchow, which I have quoted at the beginning of this address:

That no specialty can flourish which separates itself completely from the general body of Science; that no specialty can develop usefully and beneficially if it does not ever and ever again drink from the general fount, if it does not remain in relationship with other specialties, so that we all help one another, and thereby preserve for Science, at any rate, even if it should not be necessary for Practice, that unity on which our position rests intrinsically, and, I may well say also, with regard to the outer world.

SHORT PAPER

Professor H. Zwaardemaker, of Utrecht, Holland, contributed an interesting paper on "Die Vestimmung der Gehörschärfe mittelst Flüstersprache."

SECTION L — PEDIATRICS

SECTION L—PEDIATRICS

(*Hall* 7, *September* 21, 3 *p. m.*)

CHAIRMAN: PROFESSOR THOMAS M. ROTCH, Harvard University.
SPEAKERS: PROFESSOR THEODORE ESCHERICH, University of Vienna.
PROFESSOR ABRAHAM JACOBI, Columbia University.
SECRETARY: DR. SAMUEL S. ADAMS, Washington, D. C.

PROFESSOR THOMAS M. ROTCH, of Harvard University, Chairman of the Section of Pediatrics, spoke as follows:

"In opening the Section of Pediatrics I wish to express the great pleasure which I feel in welcoming to St. Louis so many representatives from different parts of the world who have come here this afternoon on account of their interest in the study of children and their diseases. It is remarkable that a more thorough investigation of the early periods of life has for so many years been neglected in all the great medical centres where other branches of medicine have been so thoroughly studied and in which such great advances have been made. It would seem that it should be the very beginning of human life which should be first understood and worked over before it would be deemed possible to understand the later and more developed periods of life and those periods in which retrograde metamorphosis takes place preparatory to and in the midst of old age. It is a fact, however, that for some reason less interest has been taken in these early periods of life than in the later ones and that some twenty or thirty years ago pediatrics was seldom spoken of, much less understood. In the last few years, however, the world has begun to appreciate that if we would have a strong race of adults, both men and women, capable of doing their work in the world in the best way according to their sex, the preparation for such work should be begun in the very earliest days of life.

In accordance with this idea it is now well understood that especial knowledge in regard to feeding infant human beings is essential to their proper development and their vigor. In response to this tendency of modern thought and to the demand which the laity is making for a class of men who feel the great responsibility which is connected with the care of children, especial attention is now given to their study in health and disease. A most remarkable impetus has taken place in the study of pediatrics, new text-books, numerous special journals and medical societies devoted to the subject of pediatrics are becoming more and more prominent and great changes have taken place in the curriculum of most of the large medical schools throughout the world. Following as I have the growth of this important subject for the past twenty years I am convinced that the same time, care, and patient research should be given to the study of pediatrics as to any other important branch of medicine. The student should first acquire a complete knowledge of the anatomy, physiology, and progressive development of the newborn human being in the stages of infancy, during the first year, and the changes from infancy to early childhood in the second year, and the various changes so significant in middle and later childhood. I believe that a thorough knowledge of the infant and child in health is a prerequisite to the proper appreciation of the conditions which occur in that child in sickness and for the possibility of the intelligent treatment of such conditions.

The great rôle which the sensitive, ill-developed, and unstable nervous system plays in its many manifestations both in health and disease shows us unquestionably how only by untiring application, patience, and thought can we hope to produce such great results in the treatment of the young as have already been accomplished in that of adults.

THE FOUNDATIONS AND AIMS OF MODERN PEDIATRICS

BY THEODORE VON ESCHERICH

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PEDIATRICS, as far as it is connected with directions as to the care of the new-born and nurslings, belongs with midwifery to the oldest branches of medicine; but in its scientific development it is among the youngest. Not until the end of the eighteenth century did it separate itself sufficiently from the trammels of obstetrics to allow the first independent book on the diseases of the new-born and children, the well-known work of Rosenstein, to appear. This contains, as do similar works which appeared in the next few years, an unsystematic account of the diseased conditions occurring in or peculiar to children, and among these only those with evident symptoms and concrete changes found especial or detailed consideration. It was not until the French Revolution that the new school of medicine came into existence, and it we must thank for the creation of scientific pediatrics as well as for the birth of modern medicine.

We will seek to sketch in a few words the origin and changes of the leading ideas up to the present time, as this best gives the trend which further development will take in the near future.

Liberation from the ban of natural philosophy and humoral pathology was brought about by the sobering influence of pathologic anatomy, which pointed in no uncertain way to visible changes in individual organs as the origin and seat of diseases. Billard is the most brilliant example of this school, which erected a clinical structure as a commentary to the anatomic changes determined by extremely numerous and carefully performed autopsies.

The lesions themselves he considered in Broussais' sense only as different grades of inflammation, and although to this day his work is still a mine of important and useful facts, it is clear that this clever conception could not by itself fulfill our practical needs, at least not in childhood, where the short duration of diseases generally prevents the occurrence of extreme anatomic changes, and where even to-day, with the help of microscopic and bacteriologic methods, we are often at a loss to bring the autopsy findings into agreement with the clinical course. This lack of agreement is most marked in the domain of the diseases of the gastro-intestinal tract in infancy, and it was on them that the opposition, keenly led by Barrier, established the "Diacrisis doctrine," with which they steered back again into the sea of humoral pathology.

Uninfluenced by these theoretic discussions, however, both parties labored to develop the new science with the newly discovered methods of exact investigation of diseases and the untrod realm of statistics, and thus they created the basis of a special pathology and therapy of childhood, of which the work of Rilliet and Barthez forms a model presentation of the whole subject. With these men the French school of pediatry ceased to occupy the leading position which it had held. The Vienna school became its heir just as in the realm of internal medicine, where under the powerful influence of Rokitansky and Skoda the same favorable conditions for development existed. Here also the clinical study was mostly founded on the basis of pathologic anatomy, as may be learned from the excellent work of Bednar, *Ueber die Krankheiten des Neugeborenen und Saüglings* (*On the Diseases of New-born and Infants*), and the important studies of Ritter of Prague. At the same time clinical symptomatology and casuistry were developed in the newly erected clinic of the St. Anna Kinderspital in Vienna under Mayr and his disciple and successor, Widerhofer, and the clinical types of disease were determined conclusively from the ample material. In a similar manner worked Henoch in Berlin, West in London, and Filatow in Moscow, so that at the end of this period the clinical knowledge and symptomatology of pediatrics were developed as far as it was possible with the simpler methods of investigation.

However important this brilliant clinical development and the sharp definition of its separateness was for the recognition of pediatrics as a distinct science, still following this direction a dead point was soon reached, from which a new route had to be opened up if dullness and routine were not to take the place of scientific investigation. With this, German pediatrics in the narrower sense of the word came into the foreground. At first it had to struggle with great difficulties on account of the lack of separate children's hospitals and of government aid, and in the first half of the century it was almost entirely under French influence. Later the peculiar organization of university policlinics, which were charged with the instruction in pediatrics, brought it about that the care of pediatrics fell to the representatives of internal medicine. I will mention here only the name of Gerhardt, the founder of German pediatrics.

It lay in the nature of this relation that in Germany, in a certain contrast to the French and Austrian schools, the common points of contact with internal medicine and the diseases of later childhood closely related to the same were preferably studied.

Even though the creation of independent chairs of pediatrics in the German universities was improperly delayed by this relation, it had the advantage that the establishment of the rapidly growing natural sciences which was taking place at this period under the influence of German internists came immediately and quickly to the service of the clinic of children's diseases. The clearer knowledge of the disease processes made possible thereby emphasized more and more the identity of most of the diseases occurring in children and in adults, and led them to seek the explanation of their differences in the peculiar characteristics of the youthful organism. Of special importance from this standpoint is the study of artificial feeding carried on with such great energy by German authors (Biedert); this demonstrated in the most convincing manner the unfinished condition of the infantile digestive organs and the consequences arising therefrom. On this basis the modern German school developed, which, by means of the methods developed especially in internal medicine, saw the aim of modern pediatrics in the investigation of those physiologic peculiarities of the childish organism, which cause the differences between its reaction under physiologic and pathologic conditions, and that observed in adults. Recently the term pathologic physiology of childhood has been used for this science. A similar road is being traversed by the rising school of American pediatry; under the leadership of Jacobi it has attached itself closely to the doctrines of the German school.

Thus we see the problems of pediatrics extended from an investigation of diseased processes peculiar to childhood, as conceived by the older pediatrists, to a general consideration of all pathologic conditions occurring during this period of life. If I characterize this as the current ruling at present and consider it the problem of the immediate future for pediatrics, it must also be stated that the solution of the part of this task belonging to physiology or general pathology is not a problem for the pediatrist alone, but can only be taken up successfully if assistance is had from workers in other lines. It is recognized that pediatrics has at all times taken an active and useful part in the building-up of general medicine and in the working-out of questions of special clinical interest, which has been made possible to a great degree by the peculiarity of its material.

Of the greatest importance for the development of modern pediatrics has been the introduction of exact methods of clinical diagnosis, which developed in the middle of last century with the great renaissance of the exact sciences. If this revolution was of great aid in the study of diseases of adults, how much more for those of early infancy, in which subjective statements and so many other diagnostic helps are lacking, and the physician is almost entirely dependent on the information derived from objective phenomena. The introduction into pediatrics of percussion and auscultation, so necessary to the knowledge of lung and heart diseases, took place relatively late and slowly. Not until in the forties were they used systematically, especially by German physicians, to whom we must also be thankful for the only book (Sahli) devoted exclusively to percussion of the organs in childhood.

Of scarcely less importance in diagnosis was the adoption of the thermometer, which, especially in the forms of rectal measurements, can be used so easily in children, even by the laity. This last fact has made it a specially important and reliable instrument. Even though the first thermometric researches were made by Roger, the development of the technic and the working-out of typic fever curves is a merit of the German school, especially that of the University of Leipsic. Together with inspection and palpation, methods which were always used, percussion, auscultation, and thermometry form the trio which is indispensable in the examination of every child, and makes possible the certain diagnosis of many previously unrecognized diseases. The endoscopic methods are used wherever the technical accomplishment in children is possible. By far the most important is the inspection of the throat and mouth, as well as the examination of the ear, all of which are comparatively easy to practice, while the laryngoscopic and opthalmoscopic methods are more rarely used. Electric examination also belongs to the physical methods of examination which are only used under exceptional circumstances, but the importance of which has been increased by the discovery of the frequent increase of electric excitability in early childhood, and radioscopic investigation, which permits a previously unsuspected insight into the conditions of the bony development as well as the changes in the more deeply situated heart and lungs.

Aspiration of pathologic fluids, introduced by Dieulafoy, is an especially useful and valuable method in childhood, and to it lumbar puncture introduced by Quincke has been added. We may say that the manifold varieties of the processes occurring in the meninges have only been made manifest by the latter. Other methods, especially the graphic, are for evident reasons less used in children, although certain authors (Rauchfuss) have succeeded in overcoming the difficulties. On the other hand the histologic methods of investigation are made of great importance by the number and variety of the anemic states, although our knowledge of the pathogenesis of these diseases has not been very much advanced thereby.

In contrast to the physical methods whose technic is generally simple, permitting a relatively rapid development of the realms of knowledge opened up by them, are the chemic methods, which are still undeveloped in spite of the high development of organic chemistry. The subjects of chemic investigation are especially the excreta of the body, the urine and the feces. The study of urine has for a long time, at least in early infancy, been improperly neglected on account of the difficulty in collecting it. Thanks to Kjelberg's suggestion the catheter is now more frequently used for the collection of urine, especially in girls, while in boys we use the Raudnitz urinal. As a result unexpected frequency and variety of albumin, in the study of which Heubner has done especial service. Also the presence of other substances useful in diagnosis; the substances shown by Ehrlich's diazo reaction, acetone, diacetic acid, etc., were found in children of all ages. As regards the morphologic elements, not considering the very great frequency of blood and tube casts, we will only mention the presence of bladder and kidney epithelium, as well as of bacteria (generally colon bacilli), as an expression of infection of the urinary tract occurring especially often in girls. The use of the centrifuge in all these examinations is very advantageous. Another very promising method is the freezing-point determination, introduced into clinical medicine by Koranyi; it has been used repeatedly in pediatrics, in the study of the milk as well as the urine.

The collection of the stools is much easier than of the urine, at least in nurslings; they also offer much more favorable opportunities for diagnosis and analysis than do the stools of adults. While in the latter it is a mass of stinking putrefaction, composed of a third of bacteria, in the nursling, the stool on account of the much shorter intestinal tract is comparable to that obtained from a fistula of the small intestine and shows, like the contents of the small intestine, acid reaction, no putrefaction, and comparatively few bacteria; food constituents if found in it at all are found in relatively slightly altered condition. Another factor which considerably increases the diagnostic importance of the nursling's stool is the similarity or at least very limited variation in the character of the food, whereby the determination of a normal stool in respect to color, amount, and chemic composition is rendered possible. For this reason the chemic analysis of the stools of infants, especially those partaking of breast milk, was undertaken comparatively early (Wegscheider). The composition of the bacterial flora was studied by me, by Booker, and more lately by Tissier, who points with right to the importance of the anaërobes. Thanks to these conditions we are able to determine the pathologic changes in the digestive process of nurslings by chemic and bacteriologic examination of their stools much earlier and more exactly, and even to make the clinical diagnosis in a not inconsiderable number of cases.

The investigation of these excreta gains much in importance because their analysis enables us to gain an insight into the metabolic processes, those mysterious processes, which even though they are not life itself are at least the source of its strength and the most immediate expression of its activity. Although this matter is so very important, for the study of growth and of the dyscrasias occurring so frequently in childhood, it has only been in recent years that we have busied ourselves with the systematic investigation of this subject, urged on by the Breslau school (Czerny). In spite of the careful investigations performed by Camerer and Heubner in the realm of energia only the first steps have been taken toward the clearing-up of these questions, their study is made very hard by the unusual technical difficulties and the vulnerability of the infantile organism.

The science, however, which has had the greatest influence upon the development of pediatrics is that which hardly twenty-five years ago proceeded from the modest workshops of Pasteur and Koch, and has won in this short time so overwhelming an influence on medical thought and research. The reason why bacteriology is of such great importance to pediatrics is that in no other period of life do the infectious diseases take so great a part. Most striking from this standpoint is the earliest infancy, the pathology of which is dominated by the septic diseases produced by the widespread bacteria of suppuration. The nature of these diseases was in most cases first recognized by the demonstration of these easily cultivated disease-breeders; in this field Hutinel and Fischl have rendered the best services. Investigation in the realm of the true epidemic diseases, the acute exanthemas and the infections of mucous membranes, has been less successful, but the example of the diphtheria bacillus, discovered by Löffler, shows how great a furthering of clinical and therapeutic knowledge is to be expected from the discovery of the disease-producers. Also the discovery that not a few infections which were formerly observed only in adults, *e. g.*, tetanus, typhoid, cerebrospinal meningitis, dysentery, etc., occur also in early childhood, was first made possible by the bacteriologic demonstration of the microorganisms concerned.

Bacteriologic diagnosis received an important enrichment by the use of the reaction products of the organism called forth by the disease-process, *e. g.*, the agglutinins of typhoid (Gruber, Widal). This method may serve not only for diagnostic purposes, but also for the discovery of unknown disease-producers, *e. g.*, colon infection and dysentery. Jehle has demonstrated in my clinic the agglutination of pneumococci by the serum of pneumonia patients already in the first days of the disease, and lately it has been made possible to isolate the streptococcus of scarlatinal angina, which is agglutinated by scarlatina immune serum in very high dilution.

Apart from this, we receive through it an unsuspected look into the healing processes and protective mechanisms of nature, which are already present in childhood, and whose further study promises important revelations concerning the peculiarity of these diseases of childhood.

These facts, discovered in the course of the last decades by the use of scientific methods, have considerably extended and clarified the study of pediatrics. In place of the comparatively small number of diseases recognizable by evident characteristics, which form the contents of the older text-books, *modern pediatrics exhibits a scientific structure, including all disturbances of the life processes, arranged according to scientific principles, and in its completeness not reached by any other specialty in medicine.* The causes of diseases as far as they are based on exogenous agencies are the same in children as in adults. It is especially bacteriologic examination, which, being in a position to show disease-producers as such, has aided considerably in showing the identity of diseases which are often so different clinically. Unfortunately, our knowledge is not sufficiently advanced to make an etiologic grouping the sole basis of our classification.

Only a small number of diseases can be considered peculiar to childhood, because they are caused by events which cannot occur in the life of adults. These are the disturbances dependent upon birth and on the change from intra-uterine to extra-uterine life, as well as those concerning growth and development. In a certain way somewhat analogous to the occupation diseases of adults are here to be reckoned the injurious effects of school attendance, as well as the acute infectious diseases which confer lasting immunity. If, in spite of this, as daily experience and medical statistics teach, the diseases of childhood show such great differences in their number and form of manifestation, as well as in their course and termination, this can only be due to the fact that *between the growing organism of the child and that of the completely developed adult great differences exist in the reaction called forth by the disease-process variations, which change constantly in the course of childhood.* The following reflection will show what close relations exist between the stage of development on the one hand and the type and course of disease on the other hand. If we take a bird's-eye view of the whole field we are struck especially by the following peculiarities occurring in the course of diseases in childhood:

1. The overwhelming frequency of fatalities in diseases, especially from functional disturbances, which explains the unsatisfactory autopsy findings in so many cases.

2. The insignificant causes producing the diseases; they are much slighter than those necessary to produce the same diseases in adults. They easily escape detection, and this explains why

all sorts of fantastic representations (influence of milk secretion, eruption of teeth, occurrence of worms), have been taken as explanations.

3. The more rapid course of the disease, terminating sometimes with a fatal ending, sometimes with recovery, but mostly with atypic and uncomplicated course because occurring in a healthy organism. (The diseases which occur in earliest infancy, in which a rapid distribution of the disease-process to other organs is observed as a result of early cessation of their function, form an exception.) Especially to be mentioned is an ability to repair anatomic lesions which are not present to the same degree in later life. (Absorption of corneal scars, Fuchs.)

4. Apart from these general differences, the course of every single disease shows special peculiarities and variations when compared to the course observed in adults; these variations are according to the degree of development and functional activity of the organs concerned, and are the greater the younger the child is.

This last fact already shows that we have to do with processes which are connected with the development of the organism, and so we are again led to the conclusion that *the key to the understanding of the special pathology of the infantile organism is to be found in the study of developmental processes.* In spite of the large number of facts which are known to us, no attempt has been made, barring a but slightly known study by Barrier, to formulate general rules and points of view for the development of the infantile organism, and to make clear its relation to the pathogenesis of the diseases of childhood, as will be attempted in the following pages.

Growth, so far as we understand by this the utilization of foodstuffs for the purpose of new formation and growth of cells (Camerer), demonstrates itself as a function of vegetative life, or more accurately expressed the inherent specific living power of the body cells, the *vital potentiality.* If we, following the idea of R. Hertwig and Exner, see in the conjunction of the male and female egg cells respectively in sexual fecundation, the exciting cause for a new and limited series of asexual cell divisions, we must suppose that the power of growth is a function peculiar to the younger and youngest cell generations. We see, then, in the germinal cell, the bearer of the entire potential energy of life, which expresses itself in at first very rapid, but gradually slowing down, growth in the size of the embryo. Unfortunately, we have no useful measure for the intensity of these life or growth processes. We may soonest consider the increase in length or bulk, as such, as has already been done by the physiologist, Haller. The first is the more suitable, as, it being the greatest of all body measures, progress in its growth is recognized before all others, and negative variations are excluded.

The weight and length curves taken from the work of Quetelet show in so far a corresponding course as their greatest rise occurs in the intra-uterine period. From the fourth to the fifth year a gradual flattening is noted in the curve which, at least in the case of the length curve, passes into the horizontal about the twentieth year. Properly speaking, then, if we would represent the intensity of the vital processes, there should occur a gradual sinking of the curve, so that it would return to the base-line at about one hundred years (as the greatest length of life), supposing that its course remains unaffected by external harmful influences. This curve, reminding one of the parabolic course of a shot hurled aloft, together with the fact that the period of ripeness and bloom of the individual is not reached until the fourth decade, has led many authors (Burdach) to the view that the greatest vital energy, together with the highest functional development and greatest power of execution occurs in the middle of life, at the highest point of this imaginary curve. This idea is certainly wrong, as not only simple consideration but also accurate physiologic study show unequivocally that *the intensity of the metabolic processes calculated for the body measurements present is greater the smaller or younger the organism, and that it continually diminishes from the ovum on through the entire course of life.* I have represented this in a second curve. The straight red, in part dotted line, shows schematically the continually sinking life-energy. The first section of this has added to it a line obtained by the application of the actual increase in length per year corresponding to the expenditure of energy for growth; it rises rapidly to the point corresponding to the beginning of fetal life. Its course corresponds to the change of the potentiality of the embryonic cell into kinetic energy, and shows that at no other time are the energy and power of life as great as in childhood.

In absolute contradiction of this idea, however, is the well-known fact, that no other period of life shows so large a number of sicknesses and deaths as the first years of life; during these years, about a quarter of those born perish. This phenomenon is observed to the same extent in the plant and animal kingdoms, as Lichtenstaedt has already shown in answer to a prize question presented before the Independent Economic Society in St. Petersburg. We have the opportunity every day to see how only a minimal part of the seeds sown broadcast develop, only a few of the fertilized ovums reach full development. The cause of this unnatural fatality, in spite of the excess in vital energy, is *that the organs necessary for the support and protection of the life-processes are at this time so undeveloped* that the slightest injury already suffices to produce an irreparable disturbance of their functions and thus destruction of life. To the extent in which these organs in the course of development grow and become stronger, the mortality falls, diminishing considerably as early as the second and third years, and reaching its lowest point in the period between the sixth and tenth years of life. The occupation of the male, the sexual activity of the female, cause a rise in the mortality from the twentieth year on. In the later age-periods the physiologic sinking and extinction of the life energy finds expression. Haller has expressed this relation in these characteristic words: "Infantes mori possunt, senes vivere non possunt." Infants may die, old people cannot live.

On Table 2 the mortality rate of a certain group of people based on the official German statistics is expressed, along with the curve of the sinking energy of life.

This survey brings me to what I may call the second law of growth. The functional development of each individual organ, measured by the absolute degree of ability for work, takes during childhood a rising course, which, however, is different for each organ, and which as a rule shows a much steeper course than that of the growth curve. Unfortunately we lack the scientific data which would enable us to display graphically the gradual growth of the development and the functional ability of the most important organs of the circulatory, respiratory, digestive tract, etc. In general, however, we may conclude on the basis of anatomic and physiologic data that this occurs comparatively quickly, while other functions, like muscular power, reach their maximum at a much later date. We may consider the overcoming of influences injurious to the organism, in other words, the degree of the power of resistance, as the common result of all these powers, which finds an expression in the statistics of the frequency of diseases and deaths. That the measure so obtained is only relatively useful, and even then only under certain definite suppositions, is seen by the consideration of the first section of intra-uterine life. Although here the organs have the least power of resistance, diseases rarely occur on account of the protected condition of the fetus. But the transition into extra-uterine life already necessitates a wonderful precision of preformed mechanisms. The least failure of these causes the greatest danger to the life of the child, and thus is explained the high mortality peculiar to the act of birth and the period immediately following. This is aided by the conditions of extra-uterine life being felt for a time by the new-born as a direct irritant, whose harmful influence can only be lessened by the most constant and proper care. The more backward the development of the child (premature birth), the less favorable the environment (poverty, illegitimacy, unsuitable nourishment), so much the smaller is the expectation of preserving the life of the child. Under unfavorable social conditions, the mortality rises to 70 % of the births, while in well-to-do families it may sink to 10 %, or even lower. Much more important than these external influences is the rapid development of the organs occurring at this time, especially that of the digestive tract, which, according to Bloch's investigations, reaches its full histologic development from the third to the fourth year of life. This rapid improvement in resisting power, associated with high vital energy, together with the care and protection which guards the child in the parents' house, brings about the period of greatest health, which continues to the end of childhood, and in which disease and death sink to a minimum. The functional development, however, is by no means completed yet with this stage. Rather now begins, after the preservation and protection of life under normal conditions has been assured, the growth of that power and reserve strength which enables the adult to take up the struggle for existence and to care for the continuance of the species under the best possible conditions; the development of strength and activity in the musculature, becoming accustomed to fatigue, to different kinds of nourishment, to climatic influences, and especially the development and training of the mental powers. Into this period falls also the strengthening of the protective influences necessary for the overcoming of infectious diseases, the acquiring of immune substances, etc.

The occurrence of this long so-called puerile period, which is given over mostly to the functional development by relatively slight increase in length and weight, belongs, like the long duration of childhood, among the most eminent peculiarities of development in the human species. There is no doubt that man owes to this slow development and maturing not only the high state of his mental and physical abilities, but also his enormous power of accommodation and functional adaptation which enables him, in contrast to lower forms of life, to exist under the widest extremes of climate, foods, and habits of life, and thereby to make himself really the lord of the world. It would, however, be a fundamental error to believe that this progressive development of functions and organs, which characterizes childhood, occurs to an equal extent in all parts, like the growth of a crystal, which increases in size by addition of equal amounts over the whole surface of the nucleus. The study of embryology, which shows such remarkable changes in the form of the embryo, protects us from this unfortunately widespread opinion which regards the child as the exact image in small size of the adult. The table devised by Langer shows the great differences which on closer observation are seen to exist between the form of the child and that of the adult. But that not only the outward form, but also the internal organs experience during the course of growth a continual change in their relative size, is shown in the table prepared at my suggestion by Oppenheimer; it displays the weight of the organs at the different years of life (compared with the weight of the organs in the new-born). The consideration of these relationships, together with the observations already mentioned, shows that the *growth of the individual organs does not occur simultaneously, but with varying intensity, so to speak by jerks, and that the order is caused by the greater or lesser importance of the developing organs for the preservation or protection of the infantile life.* This I call the third rule of growth.

The life of the child in utero and at the beginning of its extra-uterine existence is so purely vegetative as to make Plato consider seriously the question whether the new-born is actually to be considered as a human being. But just as the intellectual life is bound up with the function and development of the brain, so is the vegetative life with the function and development of the organs serving metabolic ends. The most important of these are the circulatory system, the liver, kidneys, and lymph-glands, which experience an especially early development in intra-uterine life. Beside these, only those organs are well developed in the new-born which are to serve the purposes of assimilation, the lungs and the great digestive tract, while the poorly developed skeleton and the muscles only form a thin and tender covering to these essential organs. After the great increase in the size of the body during the first year of life comes the period of skeletal development which in the fifth or sixth year is joined by that of the building-up of the muscular and mental powers. *Childhood* divides itself thus, as this short sketch shows, into a series of *phases or periods characterized physiologically by the development of definite organ systems.* Their separation is not only justifiable from a scientific, but in a higher degree even from a practical standpoint, for the conditions and necessities of life are so different for each of these periods that the kind of care and treatment is almost exclusively determined by this, that is, by the age of the individual. With the backwardness of development and the slighter variability of life-conditions due to this is connected the fact that the guiding of the life must be the more regular and careful the younger the individual is. Only in later years can individual differences and the influence of social conditions be more marked.

The most useful division of childhood not only for scientific but also for practical purposes has been found in the threefold division accepted by Vierordt :

I. Childhood : Infantia.

(1) New-born period (first week of life). Characterized by the

change from intra- to extra-uterine life and the atrophy of fetal organs; hyperemia and desquamation of the external coverings.

(2) Nursing period (first year of life). Characterized by the necessity for exclusive milk diet on account of the functional weakness of the digestive tract, also a great consumption of nourishment and considerable increase in bodily size (trebling of birth weight) marked growth of the brain ; all other functions remain backward.

(3) Milk-teeth period (second to fifth years of life). Characterized by rapid growth and formation of the skeleton, eruption of milk-teeth, learning to walk and to talk.

II. Childhood : Pueritia. (Sixth year to puberty.) Characterized by special development and exercise of the musculature, by increase of all functional activities, and by slowly progressing growth of the body. Passage of the child from the family life into social life (school). Beginning differentiation of the sexes.

III. Age of puberty (in boys from the sixteenth year, in girls of the Germanic race, from the thirteenth year on). In the latter, beginning menstruation. Awakening of sexual impulses and development of secondary sexual characteristics.

I have limited myself to giving the physiologic characteristics of these periods very briefly. On the contrary, I will try to picture more extensively their close and important relations to pathology. If we conceive of disease as the physiologic reaction and defense of the organism against the disease-producing agency, it is apparent that the physiologic condition present at the time determines the kind and course of the process. As this is true for childhood in general as compared with maturity, so it is also for the different periods of growth, which, depending on the degree of development, show such great physiologic differences. In the first period of life, especially, these are so great that under the influence of local conditions there has developed a further specialization within the limits of pediatrics of such physicians, hospitals, and clinics as are especially concerned with the care and diseases of the nursing period. Even if I do not consider this tendency to separate as justified, still it will serve to demonstrate the great compass and variation of the study of children's diseases.

The relation of the periods of growth to pathology are based, as already stated above, on the fact that the special physiologic peculiarities of each period bring with them a similarity in the course of life, and therefore opportunities for certain diseases such as do not occur at any other time. The undeveloped condition of the organs in general helps along by causing a lessened power of resistance against all disturbances, and further, the organs while growing rapidly are disposed to diseases to an especially high degree. Finally there exists an age disposition for a small number of diseases depending partly on external causes, partly on the condition of the tissues themselves. All these causes unite in individuals of one and the same period of growth, and give rise to the fact that in them a certain group of diseases is observed with especial frequency, which occur much more rarely or not at all in other periods. Thus each of these periods of growth has not only a physiologic, but also a no less marked pathologic physiognomy.

I. *Infantia*

(1) *New-born period.* Malformations, congenital and inherited diseases (lues), tumors, birth injuries (fractures, avulsions, hematomas, brain injury), disturbances in the atrophy of fetal organs (diseases of the navel), icterus neonatorum, irritation and lesions of the tender skin and mucous membranes and favored by this bacterial invasion of the body, which still lacks protective powers, local and general sepsis, gonorrheal infection.

(2) *Nursing period.* Disturbances due to incorrect quantity or intervals of feeding, relative or absolute insufficiency of digestion of food taken, especially in artificial feeding, irritation of the intestinal mucous membrane by bacterial decomposition products, or invasion of the intestinal wall leading to chronic intoxication and atrophy of the mucosa. The rapid growth of the brain is not infrequently accompanied by over-irritability of the nervous system (tetany), eclampsia and hydrocephalus. There is also a susceptibility of the skin and mucous membrane (bronchial diseases, pneumonia) as well as a marked tendency to pyogenic diseases of all sorts; specific infections, however, occur comparatively rarely.

(3) *Milk-teeth period.* Disturbance of ossification processes (beginning already during the first year) with its results (deformities of the thorax and limbs), broncho-pneumonia, etc., from rachitis. At the same time occur other dyscrasias (status lymphaticus, scrofula, anemic states). The creeping of the child on dirty floors and the tendency to put everything into its mouth in conjunction with the lack of instinct for cleanliness produces the so-called dirt infections: Numerous mouth and throat diseases, diphtheria, contagious skin diseases, helminthiasis, pertussis, even tuberculous infection of the upper respiratory or digestive tract and the consequent lymph-gland tuberculosis especially of the bronchial glands. From the latter the form of hilum phthisis peculiar to this age arises. Frequent occurrence of local and miliary tuberculosis. Defects of the intellect show their existence by delay or failure to learn to speak and grave lesions of the brain by appearing idiocy and epilepsy. Especial frequency of acute poliomyelitis.

II. *Pueritia*

Entrance into school brings with it the harmful influences connected with it — scoliosis, myopia, nervous disturbances of all sorts, and manifold contact infections, among which the acute exanthemas with their sequels, nephritis, myocarditis, are by far the most important. The desire for violent exercise explains traumatic diseases, and perhaps also the greater frequency of appendicitis. Tuberculosis, especially of the glands, is rarer and approaches the adult type. On the other hand a new and dangerous infectious disease appears in acute articular rheumatism with endocarditis and chorea.

III. *Puberty*

Furnishes, especially in the female sex, characteristic troubles, chlorosis, hysteria, psychoses, heart diseases. Otherwise the pathologic conditions pass over into those of adult life. (Demonstration of tables.)

This classification of the most common diseases of childhood is familiar to every experienced pediatrist, and by the fact that the number of diseases coming into consideration at each age is relatively limited adds considerably to the facility of diagnosis and exact appreciation. It must also be the basis of every therapeutic consideration as the medical means as well as the care of the healthy child are different for each period of growth. At introduction, however, I wish to say a few words about the treatment of diseases of childhood in general.

Even though the general principles of medical treatment in children must be the same as in adults, still the practical application of the same differs considerably according to the age of the child. For example, it is not sufficient to reduce the dose of the medicament prescribed in a given case for an adult simply according to the body-weight of the child. Rather the physiologic peculiarities of the childish organism, its intolerance for some and tolerance for other drugs, as well as the consideration of the method of dispensing suitable to childhood, necessitate in almost all cases that the choice and method of dispensing in children differ in most all instances from what is usual in adults for the same indications. The physician active in children's practice must therefore make himself familiar by special study with the therapy suitable to each period of growth.

It is similar with the physical methods of treatment. These methods also, which of late are being more and more employed, require careful adaptation to the slighter resisting power, the lack of response, of resistance, which the small patients oppose to their use. On the other hand, the smallness and transportability of the childish body, the comparatively easily overcome resistance, and the lack of anxiety from preconception, afford in many cases a desirable ease of application.

I cannot go into details in the subject of therapy. Only in general I may say that of the flood of medicaments which has in the last few years been thrown on the market by chemic industry, only a few have found a lasting place in pediatrics. The use of medicines is becoming justly more and more limited, and replaced wherever possible by physical and dietetic methods of treatment, which by long and consistent use have given brilliant results.

We may expect a really curative effect only from those measures which stimulate further, or replace the naturally powerful healing processes of the childish organism, as is strikingly done by the diphtheria antitoxin prepared by Behring. Here the pediatrists who generally are forced to travel in the beaten tracks of internal medicine, were in a position to take the leading rôle in the testing and recommending of this precious agent. A second method of treatment also used in diphtheria may here be mentioned, for the introduction of which the pediatrists exclusively are to be thanked. I refer to intubation, recommended by your genial and modest countryman, O'Dwyer, which has made the bloody operation of tracheotomy superfluous in the largest number of cases.

The greatest difference between the therapeutic problems of the pediatrist and those of the internist lies in the overwhelming importance and development of prophylaxis. The word prophylaxis in this sense is to some extent synonymous with care, inasmuch as in the education of the child because of its lacking self-determination, experience, and regulating methods, care must not only satisfy its bodily needs, but also guard it from all threatening dangers. To bring this about, the experience of adults and the general rules of hygiene, however, do not suffice. It requires special individual instruction, which can only be given by a pediatrist cognizant of the laws of child development, and carried out by persons trained in them. Clinical experience and medical statistics show that nothing influences the mortality and liability to disease in childhood as much as a carefully conducted management by experts, and in this way most if not all sicknesses may be kept away, at least in young children. Pediatrists have always known the great importance of protecting care, prophylaxis, even if only the magnificent acquisitions of the last few decades have shown them the proper way. We will attempt to sketch in a few words the most important axioms of prophylaxis for the different periods, and at the same time to touch on some of the questions which are still unsettled.

The prophylaxis in regard to birth injuries belongs to obstetrics. Here I only wish to mention the original idea of Professor Gaertner to overcome the grave asphyxia of the new-born by the introduction of oxygen into the umbilical vein. Apart from this, the task of the pediatrist is to make the surroundings of the new-born as much like the conditions existing in utero as possible, for which purpose an incubator may occasionally be useful. The delicacy of the skin and mucous membranes requires especial care in the cleansing and clothing of the child. It is well known that most of the diseases of the mouth which occur in the first few years are caused, or at least favored by mechanical injuries. Of course, another factor, infection, must assist. The slightest lesion of the coverings, however, and the ordinary pus bacteria which are ubiquitous in man's surroundings suffice already for their occurrence. To their frequency and danger the old foundling asylum statistics and hospital reports, in which 80 % to 100 % of the infants admitted died, bear witness. Through the introduction of asepsis and antisepsis into the care of nurslings, a revolution of these relations and a decrease in the septis diseases which is comparable to the precaution of puerperal fever by Semmelweiss has taken place.

The largest and most difficult task in this period of life, however, is the nourishment. The intestinal canal of the nursing child must in spite of the backwardness of its development, assimilate a sufficient quantity of food for the body-weight to treble itself.

This task is comparatively easily accomplished if the natural nourishment which suits the nursling's needs so wonderfully, mother's milk, is to be had. The difficulty is immeasurably increased, however, if the mother, from lack of milk or for social reasons is unable to nurse her child, a state of affairs which is more and more often met with. As the knowledge of metabolic processes, in spite of the great amount of work spent on it, is not sufficiently advanced to permit the setting-up of experimentally determined values, we are to-day, as in former times, required to keep to the model of mother's milk, and to make the cow's milk which is used in artificial feeding as much like it as possible.

The differences of percentage composition, which at first were considered to be of the greatest importance, we have learned to overcome completely by sufficient dilution and addition of proper amounts of fat and carbohydrates. On the other hand, in course of investigation, the cleft which existed in reference to the quality of the different foodstuffs, has widened. At least, this is true of the most important one of them, the albumin. This shows irremediable differences from the albumin of mother's milk, not only in its elementary composition and chemic reactions, but, as it comes from a different sort of animal, also in its biologic behavior. Wassermann and Hamburger have pointed out the importance of this question in infant feeding.

The thermolabile ferment-like bodies, which are contained in mother's milk, and to the presence of which I have myself drawn attention, also belong to the group of components which differ qualitatively. These substances give the breast-fed child, as they come from the blood of the mother, a part of the antitoxins and metabolic ferments contained therein, while the analogous bodies contained in raw cow's milk are of little or no value to the nursling. Therefore, it does not appear to me justified to give up for this reason the sterilization of cow's milk by heat, an acquisition which I consider one of the greatest advantages in this line, although a general tendency exists to limit the temperature and duration of the heat as much as possible, on account of the chemic changes which it causes. This is the more possible, the more cleanly the method of obtaining the milk has been, and the more carefully it has been handled before sterilization. It appears very questionable, however, whether the recently advocated addition of formalin (Behring), or the passage of electricity (Seifert), will be able to replace sterilization by heat.

An important difference between natural and artificial nourishment exists also in the method of feeding. The child at the breast receives the milk by active suckling, and (presuming feeding by its own mother) in a quantity and composition suited to its needs. The artificially-fed child has at its disposition food in unlimited quantity, and as a rule this is poured into its digestive tract in excessive amount, considering its digestive powers. Another practically important step in artificial feeding lies in strict limitation of the size and number of the feedings, in the determination of the amount of nourishment calculated either by the volumetric method or reckoned in calorics, in a word in the avoidance of the habitual over-feeding of the bottle-baby. In spite of the large amount of work done in this direction in the last decades, we must confess that we are still far from the aim of our efforts, the discovery of a substitute for mother's milk, and that nothing can replace it, especially in children backward in development or weakened by disease. On the other hand, we can say truthfully that we have succeeded in robbing the feeding with cow's milk of a large part of the danger which previously accompanied it, so that if the power to assimilate cow's milk is present at all, artificial feeding can be carried on with confidence as to the result. Of course, its proper carrying-out requires a much greater cost of time, care and pecuniary means than does breast-feeding; so that the improvement in artificial feeding is of slight or no benefit to the poor people, where it is most needed. The same difficulty also exists with regard to care, cleanliness, light and air in their dwellings.

These last factors are of special importance in the period of skeletal development. Unhygienic conditions of the surroundings, insufficient ventilation, crowding together of persons, as occurs especially among poor people and in cold weather, have, as Kassowitz has shown, an undoubted influence on the origin and severity of rachitis. Considering the great frequency and insidious beginning of this disease, it is not unnecessary to mention that the severe forms and deformities of this disease may at the proper time be prevented. In a carefully regulated diet and the use of baths, air and exercise cures, and secondarily in the administration of food preparations and medicines (phosphorus, iron, arsenic), we possess powerful aids against the development of this dyscrasia, which is so frequent at this period. In view of the change of the skeleton from the infantile to the adult type, which occurs at this time, one should also try to influence this process favorably and to prevent for example the development of the dreaded paralytic thorax by suitable means. The dangers of dirt infections are to be avoided by careful avoidance of opportunity for infection, and cleanliness; eventually, also by the use of an inclosed protective pen (Feer). I have reached the opinion that not a few of the cases of tuberculous meningitis, which is so frequent at this age, are to be traced to infection from dust in the dwelling.

In the second period of childhood, which is devoted to functional development, the task of the physician is on the one hand to bring the powers and abilities of the child to harmonious perfection, on the other hand, by an appropriate selection and direction of bodily exercises and by the proper arrangement of hours of work, to prevent exhaustion and harm. From which side the influence of the physician must act depends on the peculiarities of the child and of its guardians, and also on the customs and usages of the country. In the Germanic and Latin countries the general striving toward a better physical development does not begin until this period, while among people under English influence this has started long before.

A new factor comes into the life of the child with the school. The modern method of teaching classes in closed rooms and with a comparatively large number of hours of instruction is, from the hygienic standpoint, to be looked upon as a necessary evil. So much the more we must endeavor to compensate for the unavoidable harm by improving the school arrangements on the one hand, and by sufficient time for rest on the other. From many sides the principal task of the physician in this period is thought to be by rigorous isolation measures to guard the children against the acute exanthemas which threaten them at school. I cannot agree with this point of view under all circumstances and for all the diseases of this group. Even though every appropriate measure, even prophylactic immunization should be recommended for certain diseases like diphtheria and scarlatina, this should only be done as regards the much milder measles and varicella which attack almost every one, in so far as one tries to guard the individual as far as possible from getting the disease at a time or age in which a lessened power of resistance or a tendency to complication exists. After the sixth or seventh year this is as a rule not the case, while on the contrary in adult life measles not infrequently takes a severe course (Biedert).

The immunity acquired by passing through certain infectious diseases is an integral part of that power of resistance which man should acquire in the course of childhood. With this item is also to be classed obligatory vaccination.

Thus every period of childhood brings new and important necessities for the carrying-out of individual prophylaxis, and these might be multiplied without difficulty. The main point is the constant and careful watching over the course of the child's life during the whole but especially during the first period of growth, the care and furthering of normal development according to the sentence "medicus non sit magister sed minister naturae;" therefore in detail the taking care of those backward in development, improvement of the already developed functions, special protection of the rapidly growing organs, prevention of the tendencies to acquired or inherited diseases, protection from injurious agencies, especially infections. Disease with which the medical care generally begins is here to a certain extent a failure of preventive care, an interruption disturbing the normal process of development. In this sense the physician to whom the child is trusted becomes the friend and indispensable adviser of the family in all matters affecting the bringing-up of the child, provided they know how to appreciate the unselfish character of his work. I admit that nowadays this function of the pediatrist is employed only exceptionally and under particularly favorable conditions, and that even in the future only a limited number of families will have it accessible. But why at the close of a century which has shown such unexpected results should we hesitate to place individual prophylaxis, based on raising the power of resistance and avoidance of diseases, as the ideal aim of our efforts?

The picture of modern pediatrics would be incomplete if I were not to mention the efforts and results which have been seen in the realm of the protection of children. This was the more needed, as in many countries, especially the Anglo-Germanic, the care of poor, sick, and deserted children has always been left to private benevolence, while in the Latin countries the orphan asylums cared for the neediest group of these children. Thus were founded the children's hospitals and dispensaries, based on private donations, which to-day are to be found in every large community. These institutions are particularly important, as they form the natural centres for the practical education and scientific work from which the clinical institutes develop.

The assistance of pediatry in the reform of orphan and reformatory asylums, in the question of school physician, in the numberless societies whose purpose is the strengthening and making healthy of growing children (school gardens, vacation camps, seashore homes, etc.), goes without saying. It was the pediatrist who first pointed out the necessity for such institutions and the means of redress.

The latest movement makes the care of nursing infants its aim, the shocking mortality among whom has already been mentioned. In this direction, as in the care of children in general, at least as far as governmental aid is considered, France occupies unopposed the first rank, whom Hungary now follows with praiseworthy zeal. In most other countries there are only private undertakings; homes for cripples, milk dispensaries (so called *grottos de lait*), maternity hospitals, homes for infants. The latter serve also mostly the purposes of educating medically trained nurses. In this respect the institutions existing in the United States, among which I have become best acquainted with St. Margaret's House in Albany directed by Dr. Shaw, are especially worthy types.

All these institutions have been started by pediatrists, in part carried on by them, and sustained by their voluntary and gratuitous assistance. Thus it comes about that every year hundreds of thousands of persons whose financial position would otherwise not permit it enjoy the benefit of specialistic medical advice and treatment, and that the knowledge of a rational care of children, which is so necessary, becomes more and more widespread among the people. The warm interest and the aid which these efforts find among all classes of people show that the usefulness and humanity of these aims are fully appreciated. The great importance of these efforts for the sustaining and strengthening of coming generations is also being more and more recognized by the public authorities.

Thus our young science may, with full justification, claim to have been successful in the great task which has fallen to it in the share of public work.

THE HISTORY OF PEDIATRICS AND ITS RELATION TO OTHER SCIENCES AND ARTS

BY ABRAHAM JACOBI

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The most human of all the gods ever created by the fancy or the religious cravings of mortal men was Phœbus Apollo. It was he that gave its daily light to the wakening world, flattered the senses of the select with music, filled the songs of the bards and the hearts of their hearers with the rhythm and wonders of poetry, that inspired and reveled with the muses of the Parnassus, cheered the world with the artistic creations of the fertile brains and skillful hands of a Zeuxis and Phidias — he, always he, that inflicted and healed warriors' wounds and sent and cured deadly diseases.

In the imagination of a warm-hearted and unsophisticated people it took a god to embrace and bestow all that is most beneficent and sublime — physical, moral, and mental light and warmth; the sun, the arts, poetry, and the most human and humane of all sciences and arts, namely, medicine.

Ancient gods no longer direct or control our thoughts, feelings, and enjoyments, either physical or intellectual. The kinship and correlation of hypotheses and studies, experience and knowledge are in the keeping of the philosophical mind of man, who is both their creator and beneficiary. To demonstrate this rational affinity of all the sciences and arts, some far-seeing men planned this great Congress. The new departure — in the arrangement for it — should be an example to future general and special scientific gatherings. Indeed, some of its features were adopted by the organization committee of the International Medical Congress which was to take place at St. Louis, but was given up on account of the limited time at the disposal of the great enterprise.

Congresses are held for the purpose of comparing and guarding diversified interests. A free political life requires them for the consulting of the needs of all classes. Scientific congresses are convened to gather and collate the varied opinions, experiences, and results of many men, and to create or renew in the young and old the enthusiasm of youth. Their number has increased with the modern differentiation of interests and studies. Specialization in medicine is no longer what it was in old Egypt, namely, the outgrowth of the all-pervading spirits of castes and sub-classifications, but as well the consequence as the source of modern medical progress. It is difficult, however, to say where specialization ends and over-specialization begins, or to what extent specialization in medicine is the result of mental and physical limitation or of the spirit of deepening research; or, on the other hand, of indolence or of greed; or whether, while specialization benefits medical science and art, it lowers the mental horizon of the individual, and either cripples or enhances his usefulness in the service of mankind. For that is what medical science and art are for. José de Letamendi is perhaps correct when he says that a man who knows nothing but medicine does not even know medicine. What shall we expect, then, of one who knows only a small part of medicine and nothing beyond?

Congresses in general have been of two kinds. They were called by specialists for specialists, or they met for the purpose of removing or relieving the dangers of limitation. This is what explains the great success of international and of national gatherings, such as the German, British, American, and others, and what has given the Congress of American Physicians and Surgeons with its triennial Washington meetings its broadening and chastening influence.

Nor are medical meetings the only attempts at linking together what has a tendency to get disconnected. Look at our literature. The rising interest in the history of medicine as exhibited in Europe and lately also among us, and individual contributions, such as Gomperz's great book on Greek thinkers; or even lesser productions, such as Eymin's *Médecins et Philosophes*, 1904; or the important pictorial works of Charcot, Richet, and Holländer, prove the correlation of medicine with history, philosophy, and art.

Our special theme is the history of pediatrics and its relations to other specialties, sciences, and arts. Now Friedrich Ludwig Meissner's *Grundlage der Literatur der Pädiatrik*, Leipzig, 1850, contains on 246 pages about 7000 titles of printed monographs written before 1849 on diseases of children, or some subject connected with pedology. Of these, 2 were published in the fifteenth century, 16 in the sixteenth, 21 in the seventeenth, 75 in the eighteenth. P. Bagellardus *De aegritudinibus puerorum*, 1487, and Bartholomeus Metlinger, *Ein vast nützlich Regiment der jungen Kinder*, Augsburg, 1473, opened the printed pediatric literature of Europe. In the sixteenth century, Sebastianus Austrius, *De puerorum morbis*, Basileae, 1549, and Hieronymus Mercurialis, *De morbis puerorum tractatus*, 1583, are *facile principes;* in the eighteenth, Th. Harris, *De morbis infantum*, Amstelodami, 1715; Loew, *De morbis infantum*, 1719;

M. Andry, *L'orthopédie ou l'art de prévenir et corriger dans les enfants les difformités du corps*, 1741; Nils Rosen de Rosenstein, 1752; E. Armstrong, *An Essay on Diseases most Fatal to Infants*, 1768; and M. Underwood, *Treatise on the Diseases of Children*, 1784; also Hufeland, established pediatrics as a clinical entity; while Edward Jenner, 1798, *An Inquiry into the Causes and Effects of the Variolae Vaccinae*, opened the possibilities of a radical prevention of infectious and contagious diseases, the very subject which, a century later, is engaging the best minds and a host of assiduous workers in the service of plague-stricken mankind.

In the United States pediatrics was taught in medical schools, or was expected to be taught, by the professors of obstetrics and the diseases of women and children. The reorganization of the New York Medical College in East Thirteenth Street facilitated the creation, in 1860, of a special clinic for the diseases of the young. Instead of the united gynecologic and obstetric clinics held by Bedford, Gilman, and G. T. Elliott in their respective medical colleges, there was a single clinic for the diseases of the young exclusively. When the Civil War caused the College to close its doors forever, in 1864, the clinic was transferred to the University Medical College, and in 1870 to the College of Physicians and Surgeons. Meanwhile other medical schools imitated the example thus presented. The teachers were classed amongst the "clinical" professors; only in those schools which are forming part of universities and are no longer proprietary establishments, a few now occupy the honored position of full professors; in a very few the professor of pediatrics is a full member of the "faculty."

In the English Colonies of America the earliest treatise on a medical, in part pediatric subject was a broadside, 12 inches by 17. It was written by the Rev. Thomas Thacher, and bears the date January 21, 1677–8. It was printed and sold by John Foster of Boston. The title is "a brief rule to guide the common people of New England how to order themselves and theirs in the Small-Pocks, or measles." A second edition was printed in 1702.

Before and about the same time in which American pediatrics received its first recognition at the hands of the New York Medical College, European literature furnished a new and brilliant special literature. France which almost exclusively held up the flag of scientific medicine during the first forty years of the eighteenth century, furnished in C. Billard's *Traité des maladies des enfants nouveau-nés*, 1828, and in Rilliet's and Barthez's *Traité clinique et pratique des maladies des enfants*, 1838–43, standard works which were examples of painstaking research and fertile observation. England, which produced in 1801 I. Cheyne's *Essays on the Diseases of Children*, gave birth to Charles West's classical lectures on the diseases of infants and children in 1848, and F. Churchill's treatise in 1850.

The German language furnished a master-work in Bednar's *Die Krankheiten der Neugebornen und Säuglinge*, 1850–53. A. Vogel and C. Gerhardt, both general clinical teachers, gave each a textbook in 1860, Henoch in 1861; and Steffen in 1865–70, published a series of classical essays.

The number of men interested in the study and teaching of pediatrics grew in proportion to the researches and wants of the profession at large. That is why three large and influential cyclopedias, the works of many authors, found a ready market, namely, C. Gerhardt's *Handbuch der Kinder-Krankheiten*, 1877–93; John M. Keating's *Cyclopedia of the Diseases of Children Medical and Surgical*, 1889–90, and I. Grancher's and I. Comby's *Traité des Maladies des Enfants*, in five volumes, the second edition of which is being printed this very year.

The collective and periodic literature of pediatrics began at a comparatively early time. There was a period towards the end of the eighteenth century when the influence of Albrecht von Haller seemed to start a new life for German medical literature before it lost itself again in the intellectual darkness of Schelling's natural philosophy, from which it took all the powers of French enthusiasm and research, and the epoch-making labors of Skoda, Rokitansky, and finally Virchow, to resuscitate it. About that early time of Haller, there appeared in Liegnitz, 1793, a collection of interesting treatises on some important diseases of children (*Sammlung interessanter Abhandlungen über etliche wichtige Kinderkrankheiten*). France followed in 1811 with a collection bearing the title *La Clinique des Hôpitaux des enfants, et revue retrospective médico-chirurgicale et hygiénique. Publiées sous les auspices et par les médecins et chirurgiens des hôpitaux consacrés aux maladies des enfants.* Next in order are five volumes of Franz Joseph von Metzler's *Sammlung auserlesener Abhandlungen über Kinderkrankheiten*, 1833–36; twelve fascicles under the title *Analekten über Kinderkrankheiten oder Sammlung ausgewählter Abhandlungen über die Krankheiten des Kindlichen Alters; la clinique des Hôpitaux des enfants, Redacteur en chef Vanier*, Paris, 1841; and I. Behrend and A. Hildebrandt, *Journal für Kinderkrankheiten*, which appeared regularly from 1843 to 1872. It gave way to the *Jahrbuch für Kinderheilkunde*, which appeared in quick and regular succession from 1858 to the present time. Three series of Austrian journals between 1855 and 1876 consisted of a dozen volumes only. They contain among other important contributions the very valuable essays of Ritter von Rittershayn, who deserved more recognition during his life and more credit after his death, for his honesty, industry, and originality, than he attained.

Special pediatric journals have multiplied since. The United States has two, France three, Germany five, Italy two, Spain one.

As long as they are taken by the profession we should not speak of over-production. I attribute their existence to the general conviction that there is no greater need than of the distribution of knowledge of the prevention and cure of the diseases of the young. The literature of pediatrics seems to prove it. Not 7000, as before 1850, not even 70,000 titles of books, pamphlets, and magazine articles exhaust the number.

Pediatric societies have increased at the same rate. The American Medical Association and the British Medical Association founded each a section twenty-five years ago, the New York Academy of Medicine in 1886. The American Pediatric Society was founded in 1889, the Gesellschaft für Kinderheilkunde connected with the German Gesellschaft der Aerzte und Naturforscher in 1883, the English Society for the Study of Disease in Children, in 1900. There are pediatric societies in Philadelphia, in the State of Ohio, in Paris, Kiew, St. Petersburg, and many places, all of them engaged in earnest work which is exhibited in volumes of their own or in the magazines of the profession. If we add the annual reports of hundreds of public institutions, which are so numerous indeed that a large volume of S. Hügel, *Beschreibung sämmtlicher Kinderheilanstalten in Europa*, was required as early as 1848 to enumerate them; and an enormous number of text-books of masters, and of such as are anxious to become so, and monographs, and essays, and lectures, and notes preliminary and otherwise, which fill the magazines that most of us take or see, and some of us read — we may form an idea to what extent a topic formerly neglected has taken hold of the conscience and the imagination of the medical public.

Before 1769 there was no institution specially provided for sick children. They were admitted now and then to foundling institutions and general hospitals. In that year Dr. G. Armstrong established a dispensary in London which was carried on until he died. A similar institution was founded in Vienna by Dr. Marstalier, in 1784. Goelis took charge of it in 1794, L. Politzer developed it, and it is still in existence. Before the French Republic was strangled, it founded the first and largest child's hospital in Europe, L'Hôpital des Enfants malades, in 1802. The Nicolai Hospital was established in St. Petersburg in 1834 by Dr. Friedburg; the St. Anne's Child's Hospital in Vienna, 1837, by Dr. Ludwig Mauthuer; and the Poor Children's Hospital of Buda Pesth in 1839 by Dr. Schöpf Merei, who afterwards founded and directed the Child's Hospital of Manchester, England.

Since that time the increasing interest in the diseases of children on the part of humanitarians and of physicians and teachers has multiplied children's hospitals. Most of them are small, but they are numerous enough both to exhibit and disseminate the sense of responsibility to the sick and to the necessities of teaching. The United States has been the last country to participate in these endeavors. The mostly proprietary medical schools did not find pediatric teaching to their advantage, and it took the hearts and purses of the public a long time to be opened. The waves of humanitarianism, sometimes directed by a church, and the demands of science have finally overcome previous indolence. There are many general hospitals that gradually opened special children's wards. You find pediatric hospitals in some of the larger cities—New York, Boston, Philadelphia, Albany, St. Louis, and others. It has so happened, however, that real specialties have appealed more to the general sympathy than pediatrics. That is why the number of beds in orthopedic and other special hospitals are mostly favored. Practical teaching has not been extensive. Children's hospitals that should be used for that purpose, and that are directly connected with a medical school, are but few. It has taken the medical faculties even of universities too much time to appreciate the necessity of special and well-regulated bedside teaching. In some instances lay trustees, guided by their medical advisers, have opened their wards before faculties have consented to open their eyes. At the present time, however, there is hardly a great medical school that does not give amphitheatre or bedside instruction, either in a children's ward of a general hospital or in a special children's or babies' hospital. To a certain extent the teaching of pediatrics in a general hospital has its great advantages. It is not a specialty like that of a special sense or a tissue. For the purpose of study it had to be segregated, but it will never be torn asunder from general medicine. Vogel and Gerhardt were both general clinicians.

The comparative anatomy and physiology, hygiene, etiology, and nosology of pediatrics have been discussed before you by one of the most prominent pediatrists of our era. It will be my privilege to explain, as far as time will permit, its relation to general medicine, to embryology and teratology, obstetrics, hygiene, and private and public sanitation, to therapeutics both pharmacal and operative, and to the specialties of otology, ophthalmology, dermatology, and the motor system, to pedagogy, to neurology and psychiatry, forensic medicine and criminology, and to social politics.

Infancy and childhood do not begin with the day of birth. From conception to the termination of fetal life evolution is gradual. The result of the conception depends on parents and ancestors. Nowhere are the laws of *heredity* more perceptible than in the structure and nature of the child. Physical properties, virtues and sins, and tendencies to disease may not stop even with the third or fourth generation. Hamburger and Osler trace an angio-neurosis through six generations, the first case in the series being observed by Benjamin Rush. In many instances still-births, early diseases, atrophy, and undue mortality of the young depend on ante-natal happenings. The condition and diet of the mother influences her offspring. The danger of a contracted pelvis, and the necessity of premature delivery may be obviated by the restriction of the diet, or even by appropriate (thyroid and other) medication of the pregnant woman. Experience and experiment tell the same story. The continued practice of preventing conception causes endometritis. Alcoholism causes chronic placentitis, premature confinement, or still-birth. So does chronic phosphorus and lead poisoning. Fortunately, however, the usual medication resorted to during labor is rarely dangerous, for even morphine or ergot doses given to the parturient woman on proper indications affect the newly-born rarely, and chloroform anesthesia almost never.

Scanty amniotic liquor, by the prevention of free intra-uterine excursions, may cause club-foot; or close contact of the surfaces of the embryo and the membranes give rise to adhesions of the placenta and the head, to filaments and bands whose pressure or traction produces grooving or amputation of limbs, cohesion of toes or fingers, umbilical, meningeal, encephalic, or spinal hernia; not in extra-uterine pregnancy only, where such occurrences are very frequent. Even the majority of harelips and fissured palates have that origin. Arrests of development and fetal inflammation are the headings under which most of the anomalies of the newly-born may be subsumed; congenital diseases of the ear and of the heart may result from either cause or from both. Obstructions of the intestines, the rare closures of the esophagus, the ureter, and the urethra, with hydro-nephrosis and cystic degeneration of the kidneys, are probably more due to excessive cell proliferation in the minute original grooves than to inflammation.

The insufficient closure of normal embryonic fissures or grooves explains many cases of spina bifida, many of encephalocele, most of the split lips and palates, all of porencephalus, bifid uvula and epiglottis, pharyngeal and thyroglossal fistulæ, the communications between the intestinal and uro-genital tracts, and the persistency and patency of the urachus.[1]

Heredity need not show itself in the production of a fully developed disease. It exhibits itself normally either in equality or resemblances, either total or partial, of the body, or some one or more of its external or internal organs. In this way it may affect the nervous, the muscular, the osseous, or other tissues. That is why dystrophies in different forms, obesity, achondroplasia, hyperplasia, or atrophy may be directly inherited, while in other cases the disposition to degeneration only is transmitted.

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[1] J. W. Ballantyne, in his manual of ante-natal pathology and hygiene, 1902, has a separate chapter on the relations of ante-natal pathology to other branches of study, to general pathology, to the biological sciences, such as anatomy, embryology, physiology, botany, and zoölogy, and to the medical, including obstetrics, public health, pediatrics, medicine, psychology, dermatology, surgery, orthopedics and medical jurisprudence, finally to gynecology and neo-natal ;

Hereditary degeneracy is often caused by social influences. The immoral conditions created by our financial system make women select not the strong and hearty and the young husband, but the rich and old, with the result of having less and less vigorous children. Certain professions, the vocations of soldiers and mariners, and subordinate positions of employees in general, enforce complete or approximative celibacy, with the same result. The nations that submit to the alleged necessity of keeping millions of men in standing armies, are threatened with a degenerated offspring, for not only do they keep the strongest men from timely marriages, but they increase prostitution and venereal diseases, with their dire consequences for men, women, and progeny. Wars lead to the same result in increased proportion, for tens and hundreds of thousands of the sound men are slain or crippled, or demoralized. Those who are inferior and unfit for physical exertions remain behind and procreate an inferior race; those who believe with Lord Rosebery that an empire is of but little use without an imperial race will always, in the interests of a wholesome civilization, object to the untutored enthusiasm which denounces the "weakling," and the "craven cowardice" of those who believe in the steady evolution of peace and harmony amongst men, and, in sympathy with the physical and moral health of the present and future generation, will prefer the cleanly and washed sportsmanship of an educated youth to that of the mud-streaked and blood-stained man-hunter.

A great many diseased conditions cannot be thoroughly understood unless they be studied in the evolving being. Tumors are rarely inherited, but many of them are observed in early life. Lymphoma, sarcoma, also lipoma and carcinoma, and csytic degeneration, are observed at birth, or within a short time after, and seem to favor Cohnheim's theory, according to which many owe their origin to the persistence in an abnormal location of embryonic cells. This theory does not exclude the fact that congenital tumors may remain dormant for years or decades and not destroy the young.

So much on some points connected with *embryology* and *teratology*. The connection with *obstetrical practice* is equally intimate. Three per cent of all the mature living fetuses are not born into postnatal life this very day. To reduce the mortality even to that figure, it has taken much increase of knowledge and improvement in the art of obstetrics to such an extent that it has become possible by Cesarean section not only to save the fetus of a living, but also of a dead mother, for the fetus in her may survive the dying woman.

But after all, many a baby would be better off, and the world also, if it had died during labor. There are those, and not a few, who are born asphyxiated on account of interrupted circulation, compression of the impacted head, or meningeal or encephalic hemorrhage, which destroys many that die in the first week of life. Those who are not so taken away may live as the result of protracted asphyxia only to be paralytic, idiotic, or epileptic. Many times in a long life have I urged upon the practitioner to remember that every second added to the duration of asphyxia adds to the dangers either to life or to an impaired human existence. Besides fractures, facial or brachial paralysis, cephalhematoma and hematoma of the sterno-cleido mastoid muscle, gonorrheal ophthalmia, with its dangers to sight and even life, may be daily occurrences in an obstetrician's life. All such cases prove the insufficiency of knowledge without art, or of art without knowledge, and the grave responsibility of the practical obstetrician. To lose a newly-born by death causes at least dire bereavement; to cripple his future is not rarely criminal negligence.

Within a few days after birth the obstetrician or the pediatrist has the opportunity of observing all sorts of microbic infections, from tetanus to hemorrhages or gangrene, and the intense forms of syphilis. Not an uncommon disease of the newly-born and the very young is nephritis. It is the consequence, in many cases, of what appears to be a common jaundice, or of uric acid infarction, which is the natural result of the sudden change of metabolism. The diverticula of the colon, as described by Hirschsprung and Osler, and what nearly 40 years ago I characterized as congenital constipation, which depends on the exaggeration of the normally excessive length of the sigmoid flexure, belong to the same class. Their dangers may be avoided when they are understood. Of the infectious diseases of the embryo and the fetus, it is principally syphilis that should be considered; amongst the acute forms variola and typhoid are relatively rare.

What I have been permitted to say is enough to prove the intimate interdependence and connection between pediatrics and the diseases of the fetus with embryology and teratology, obstetrics, and some parts, at least, of social economics.

After birth there are anomalies and diseases which are encountered in the infant and child only. There are also, common to all ages, though mostly found in children, such as exhibit a symptomatology and course peculiar to them. The first class, besides those which are seen in the newly-born, is made up mostly of developmental diseases, — scrofula, rachitis, chlorosis. The actual or alleged ailments connected with dentition, most forms of stomatitis, Bednar's so-called aphthae, the ulceration of epithelial pearls along the raphe, amygdalitis, pharyngitis, adenoid proliferations, latero- and retro-pharyngeal abscesses belong here. Infectious diseases, such as variola, diphtheria, scarlatina, measles, pertussis, and tuberculosis of the glands, bones, joints, and peritoneum, have been most successfully studied by pediatrists or those clinicians who have paid principal attention to pedology. Meissner prints the titles of more than 200 actual monographs on scarlet fever published in Europe before 1848. Pleurisy and pneumonia of the young have their own symptomatology. Empyema is more frequent and requires much more operative interference. Tracheotomy and intubation are mostly required by the young, both on account of their liability to edema of the larynx and to diphtheria, and of the narrowness of the larynx. Of invagination, 25% occur under one year, 53% under 10. Appendicitis, sometimes hereditary and a family disease, would long ago have been recognized as a frequent occurrence in the young if it had not been for the difficulty, mainly encountered in the young, and sometimes impossibility of its diagnosis. That is what we have been taught by Hawkins and by Treves, and lately by McCosh. Operations on glandular abscesses, osteotomies, and other operations on the bones and joints, particularly in tuberculosis, and on malformations such as have been mentioned, require the skillful hand of the operating physician in a great many instances. Omphalocele, exstrophy of the bladder, undescended testicle, spermatic hydrocele, multiple exostoses, imperforate rectum, atresia of the vagina, or an occasional case of stenosed pylorus, belong to that class, some requiring immediate operation, some permitting of delay. It is principally infancy that demands removals of angioma, which are almost all successful, and of hygroma, mostly unsuccessful, mainly when situated on the neck and resulting from obstruction of the thoracic duct sometimes connected with thrombosis of the jugular vein. Childhood requires correction of kyphosis and scoliosis, and operations for adenoids and hypertrophied tonsils, and furnishes the opportunities for lumbar puncture and laparotomy in tubercular peritonitis; also supra-pubic cystotomy, and mastoid operations. That gum-lancing is no operation indicated or permissible in either the young or adult, and not any more so in the former than in the latter, is easily understood by those who acknowledge its necessity only in the presence of a morbid condition of the gums or teeth, and not when the physiological process of dentition exhibits no anomaly. It scarcely ever does. Altogether operating specialists would work and know very much less if a large majority of the cases were not intrusted to them by the pediatrist, who recognizes the principle that those who are best fitted to perform it should be trusted with important medical work. So well is the seriousness and difficulty of operative procedures, as connected with diseases of children, recognized by experts, that 1500 pages of Gerhardt's handbook are dedicated to external pathology and operations, and that special works, besides many monographs by hundreds of authors, have been written by such masters as Guersant, Forster, Bryant, Giraldès, Holmes, St. Germain, Karewski, Lannelongue, Kirmisson, and Broca.

Ear specialists recognize the fact that otology is mostly a specialty of the young. The newly-born exhibit changes in the middle ear which are variously attributed to the presence of epithelial detritus, to the aspiration of foreign material, or to an edema *ex vacuo* occasioned by the separation of formerly adjacent mucous surfaces. Pus is found in the middle ear of 75 % of the still-born or of dead nurslings. It contains meconium, lanugo, and vernix. Aschoff [1] examined 50 still-born, or such as had lived less than two hours; 28 of them had pus in the middle ears (55 %). He also examined 35 infants that had lived longer than two hours; 24 had pus (70 %). Evidently the latter class had been exposed to a microbic invasion. The diagnosis in the living infant is very difficult, mostly impossible, on account of the large size of the Eustachian tube, which after having admitted the infection, allows the pus to escape into the pharynx and the rest of the alimentary canal. Many of the newly-born that die with unexplained fevers perish from the septic material, or its toxins, absorbed in the middle ear or the intestines. Nor are older children exempt. Geppert (*Jahrb. f. Kind.*, XLV, 1897) found a latent otitis media in 75 % of all the inmates of the children's hospitals. Both latent and known otitis is often connected with pneumonia, or with pneumonia and enteritis. In individual cases it may be difficult to decide which of the two or three is the primary, which the secondary affection.

The great vascularity of the middle ear, but still more the accessibility of the funnel-like Eustachian tube in the infant, renders otitis media very frequent. Schwartze's assertion that otitis media furnishes 22 % of all ear cases in general or special practice is surely correct. Besides, difficult hearing is very frequent in the young, a fact of the greatest import to pedagogy. As early as 1886 Bezold found that of 1900 school-children 25 % had only one third, and 11 % of the others only one fifth of normal hearing. The frequent affections of the nose and pharynx in the young explain these facts and exhibit the possibilities of prevention. Finally, the immature condition of the mastoid process and of the floor of the external canal and the frequency of primary bone tuberculosis, are best appreciated by the practitioner, general or special, who deals with their abscesses.

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[1] Aschoff, *z. f. Ohrenh.* vol. XXXI.

Whether deaf-mutism is the result of consanguineous marriage cannot be definitely asserted. It is not often hereditary, quite often it appears to be the result of family alcoholism; it sometimes depends on arrest of development and fetal inflammation, but is more frequently an acquired condition. Not rarely children are affected after they have been able to speak. The majority of cases are caused by cerebral or cerebro-spinal inflammation. According to Biedert, 55 % are of that class, 28 % are caused by infectious diseases (cerebrospinal meningitis, scarlatina, typhoid fever, diphtheria, also variola and measles), 3.3 % by injuries, and only 2.5 % are original ear affections. Thus many of the congenital cases, and most of the acquired, are preventable. More and more will our deaf-mute institutions avail themselves of this knowledge, and will learn how to teach their children not only how to read and write, but also how to hear.

Not to the same, but to a great extent, pediatrics and *ophthalmology* join hands. Infectious diseases, such as diphtheria, affect the conjunctiva and sometimes the cornea. Syphilis of the cornea, with or without chronic iritis, is the form of parenchymatous or diffuse keratitis. A frequent tumor in the eye of the young is glioma, and frequent symptomatic anomalies are strabismus and nystagmus — both of them the results of a great many and various external or internal causes, with sometimes difficult diagnoses.

The connection of pedology with *dermatology* is more than skin deep; some of the most interesting problems of the latter must be studied on antenatal and postnatal lines. The congenital absence of small or large parts of the surface is probably due to amniotic adhesions; seborrhea and the mild form of lichen, also the furunculosis of infant cachexia and atheroma, to the rapid development, in the second half of intra-uterine life, of the sebaceous follicles; ichthyosis, to the same and to a hypertrophy of the epidermis and the papillæ of the corium, sometimes with dilatation of their bloodvessels and with sclerosis of the connective tissue. Congenital anomalies, such as lipoma, sarcoma, naevus pigmentosus, open all the questions of the embryonal origin of neoplasms; and the eruptions on the infant surface unclose to the specialist the subject of infectious diseases. We recognize in the pemphigus of the palms and soles syphilis; in herpes, gangrene, and in what I have described as chronic neurotic pemphigus, the irritable nervous system; in eczema, constitutional disturbances of the nutrition; in erythema, local irritation or intestinal auto-infection; in isolated or multiple forms ranging between hyperemia and exudation, the effect of local irritation or the acute or chronic influence of drugs. A dermatologist who knows no embryology or pedology, a pediatrist who knows no dermatology, is anything but a competent and trustworthy medical practitioner.

The diseases of the *muscles* interest the pediatrist, the surgical specialist, the orthopedist, and the neurologist, to an equal extent. Many forms of myositis are of infectious origin. Amongst the special forms of muscular atrophy it is the hereditary variety which concerns the first. The spinal neuritic atrophy form the myogenous progressive dystrophy, including the so-called pseudo-hypertrophy, Thomson's congenital myotonia, and atrophy or absence of muscles — mainly the pectoral, but also the trapezius, quadriceps, and others — no matter whether they are primary or myogenous (this probably always when there is a complication with progressive dystrophy), are of special interest. I need not do more than mention torticollis in order to prove that neither the special pediatrist nor the special orthopedist, nor the general surgeon can raise the claim of ownership.

The relations of pediatrics to *forensic medicine* are very close. Nothing is more apt to demonstrate this than the immense literature in every language on infanticide and all the questions of physiology, physics, and chemistry connected with that subject. The monographs and magazine essays of the last two centuries written on the value or the fallacy of the lung test in the dead newly-born would fill a small library. Much attention has been paid by physicians and by forensic authors to lesions and fractures of the newly-born head, and to anomalies of the female pelvis causing them. Apparent death of the newly-born and the causes of sudden death in all periods of life have been studied to such an extent as to render negative results of police investigation and of autopsy reports less numerous from year to year. Most sudden deaths receiving the attention of the authorities occur in the young. There were (Wm. Wynn Westcott, in *British Med. Jour.*, 1903) in England and Wales during ten years 15,009 overlain infants; in 1900, 1774. In Liverpool, out of 960 inquests there were 143 on babies that had died of such suffocation by accident or malice aforethought; in London, in 1900, 615; in 1901, 511; in 1902, 588. In London they had annually 8000 official inquests, one in 14 of which were on overlain infants. The etiology of sudden deaths would be far from complete, indeed the most difficult questions could not be solved except by the facilities furnished by the observations on the young. Foreign bodies in the larynx, beans, shoe-buttons, and playthings generally, even ascarides (Bouchut), bones and pieces of meat aspirated during vomiting, acute edema of the glottis, aspiration of a long uvula, or of the retracted tongue, the rupture of a pharyngeal abscess or of a suppurating lymphoid body into the trachea, a sudden swelling of the thymus in the narrow space between the manubrium and vertebral column, which at best measures only 2.2 cm., even a coryza in the narrow nose of a small infant filled or not with adenoids — are causes of sudden death.

The *nervous system* furnishes many such cases. It is true there is no longer a diffuse interstitial encephalitis, such as Jastrowitz would have it, nor is the hypertrophy of the brain by far so frequent as Hüttenbrenner taught, but there are sudden collapses and deaths by falls on the abdomen, by sudden strangulation of large herniae, and other shocks of the splanchnic nerve. There are sudden and unexplained deaths in unnoticed attacks of convulsions, in the first paralytic stage of laryngismus stridulus, in glottic spasms from whatever cause, in the paralysis — or, according to Escherich, laryngo-spasm — of what since Paltauf has been denominated status lymphaticus, in cerebral anemia, no matter whether it is the result of exhaustion or, as Charles West taught us 60 years ago, from the mere change of position of a pneumonic or otherwise sick baby, when suddenly raised from its bed. Or death may occur suddenly (a very frequent occurrence) in the heart-failure of parenchymatous degeneration of the heart-muscle as it occurs in and after diphtheria, influenza, and other infectious diseases, or in the acute sepsis of appendicitis and other intraperitoneal affections, whether recognized or not. For the absorbing power, even of the normal peritoneum, is enormous. Of a very acute infection ("infectio acutissima") Wernich spoke as early as 1883.

In gastroenteritis, the terminating broncho-pneumonia may destroy life quite suddenly; there is a capillary bronchitis of the very young with no cry, no moan, and no cough, but with sudden death; there are in extreme atrophy fatal emboli into the pulmonary, sometimes renal, more often cerebral arteries. There are the cases of uremic convulsions, sudden, with sudden death, which are often taken to be merely reflected or "providential," because the frequency of acute nephritis in the newly-born and the infant, with its fever and its uremia, in spite of the publications of Martin and Ruge, Virchow, Orth, Epstein, and my own, is not yet fully appreciated. That is so much the more deplorable as the diagnosis of nephritis at any age is readily made by the examination of the urine, which is so easy to obtain in the young. Other suddenly fatal conditions, such as the acute or chronic sepsis I mentioned before, often quite unsuspected, entering through the umbilicus, the intestine, or the middle ear, are quite frequent.

I have been careful not to mention any cause of death that may just as well be and has been studied in the adult: hemorrhages, the many forms of sepsis of later periods of life, poisons, such as carbolic acid and iodoform, intense cold or heat, insolation, etc., for it is my duty to exhibit the relation to forensic medicine of pediatrics only.

Forensic medicine has to guard the interests of all. Nothing in all medicine is more difficult than the discovery of the cause of death. The best knowledge of the advanced practitioner, of the pathologist, of the chemist, of the bacteriologist, of the obstetrician, should be at the service of the people. Every European country understands that and acts on that knowledge. Our own Massachusetts has broken away from the coroner's institution, which was a fit authority for a backwoods municipality, but is so no longer for a cultured people of eighty millions. Now and then, even an expert, or a body of experts do *not* succeed in discovering the cause of death. What shall we say of a system which *now and then does* discover the hidden cause of a sudden death? When the New York State Legislature half a year ago passed a bill abolishing the no longer competent office of coroner, our good cultured mayor, a gentleman and author, vetoed it for the reason that the new law was not perfect. It was not pronounced perfect by anybody, no law is nor ever was. That is why it appears he prefers something that always was and is, and always will be perfect, namely, the absurd incompetency and anachronism of the coroner's office. That is perfect. I have not hesitated to express myself strongly and positively, for I have been called upon to speak to you about the relation of pediatrics to other sciences and arts — politics included, than which there is no more profound practical and indispensable science and art. The greatest historical legislators understood that perfectly well, when they knew how to blend hygiene and religion with their social and political organization.

One of the greatest questions which concerns at the same time the practical statesman, the humanitarian and the pediatrist, is that of the *excessive mortality* of the young. The Paris Academy of Medicine enumerated in its discussions of 1870 the following amongst its causes: Poverty and illness of the parents, the large number of illegitimate births, inability or unwillingness on the part of mothers to nurse their offspring, artificial feeding with improper material, the ignorance of the parents in regard to the proper food and hygiene, exposure, absence of medical aid, careless selection of nurses, lack of supervision of baby-farms, general neglect and infanticide. *If there be* anybody who is not quite certain about the relationship of sciences and arts, he will still be convinced of the correlation and coöperation of ignorance, indolence, viciousness, and death, and shocked by the shortcomings of the human society to which we belong. Most of them should be avoided. Forty per cent of the mortality of infants that die before the end of the first year takes place in the first month. That is mostly preventable. A few years ago the mortality of the infants in the Mott Street barracks of New York City was 325 per thousand. Much of it is attributable to *faulty diet.*[1]

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[1] Measures taken for the purpose of obtaining wholesome milk are not quite

Amongst those who believe in the omnipotence of chemical formulae, there prevails the opinion that a baby deprived of mother's milk may just as readily be brought up on cow's milk; that is easily disproved. In Berlin they found that amongst the cows'-milk fed babies under a year the mortality was six times as great as amongst breast-fed infants. Our own great cities gave us similar or slightly smaller proportions until the excessive mortality of the very young was somewhat reduced by the care bestowed on the milk, introduced both into our palaces and tenements. Milk was examined for bacteria, cleanliness, and chemical reaction. It was sterilized, pasteurized, modified, cooled, but no cow's milk was ever under the laws of nature changed into human milk, and with better milk than the city of New York ever had, its infant mortality was greater this summer than it has been in many years.

That hundreds of thousands of the newly-born and small infants perish every year on account of the absence of their natural food is a fact which is known and which should not exist. Why do we kill those babies or allow them to be killed? Why is it that they have no breast-milk? A large number of women work in fields, still more in factories. That is why their infants cannot be nursed, are farmed out, fed artificially, with care, or without it, and die. It is the misrule prevailing in our social conditions which compels them to withhold milk from the infant while they are working for what is called bread for themselves and their families. Many of these women, it is true, would not have been able to nurse their newly-born, for their own physical condition was always incompetent. The same may be said of women in all walks of life. Insufficient food, hard work, care, hereditary debility and disease, tuberculosis, alcoholism of the woman's own father, modified syphilis or nervous diseases in the family — aye, the inability of her own mother to nurse her babies, are ever so many causes why the mother's fountain should run dry. Statistics from large obstetrical institutions (Hegar) prove that only about 50 % of women are capable of nursing their offspring for merely a few weeks. In the presence of such facts what are we to say of the refusal of well-situated and physically competent women to nurse their infants? I do not speak of the "400," I mean the 400,000 who prefer their ease to their duty, their social functions to their maternal obligations, who hire strangers to nurse their babies, or worse yet, who make-believe they believe the claims of the infant-food manufacturers, or are tempted by their own physicians to believe that cow's milk casein and cow's milk fat may be changed

new. Regulations were given in Venice, 1599, for the sale of milk. Milk and its products of diseased animals were forbidden. The Paris municipality of 1792 enjoined the farmers to give their cows healthy food. Coloring and dilution of milk were strictly forbidden, and in 1792 they knew in France how to punish transgressors.

into woman's casein and fat, that chemistry is physiology, that the live stomach is like a dead laboratory bottle, that the warmth of the human bosom and that of a nursing flask are identical, and that cow's milk is like human milk when it carries the trademark "Certified," or "Modified." Physiological chemistry itself teaches that the phosphorus combinations in woman's milk in the shape of nuclein and lecithin are not contained in cow's milk, and that the large amounts of potassium and sodium salts contained in cow's milk are dead weights rather than nutrients, and particularly the large amount of calcium phosphate occurs in a chemical, not in a physiological combination. But lately, by no means the first time, Schlossmann and Muro (*Münch. med. Woch.*, 1903, no. 14) have again proved that the albuminoids of woman's and cow's milk are essentially different, both in their lactalbumin and the globulin, and Escherich and Marfan, that every milk has its own enzymes.

The quantitative and many of the qualitative differences of cows' and human milk have been known a long time. No addition or abstraction of salts, no addition of cow's fat will ever change one into the other. But it appears that every new doctor and every new author begins his own era. There is for most of modern writers no such thing as the history of medicine or of a specialty, or respect of fathers or brothers. In modern books and essays you meet with footnotes and quotations of the productions of yesterday that look so erudite, but also with the new discoveries of old knowledge which you would recognize if the quotation-marks had not been forgotten by accident. So it has happened that many learn for the twentieth time that the knowledge of the minimum amount of required food is a wholesome thing, that the amount of animal fat in infant food is easily overstepped, that we have discovered that the Dutch had a clever notion when they fed babies on buttermilk with reduced fat; we are even beginning to learn what our old forefathers practiced a hundred years ago, and physiologists taught a third of a century ago — namely, that the newly-born and the very young infant not only tolerate small quantities of cereals but that they improve on it. Indeed, the names of Schiller, Korowin, and Zweifel have been rediscovered. We have also learned — just lately, it appears — what was always known, that morning and night, idleness and work, health and illness, while altering the chemical composition of woman's milk do not necessarily affect its wholesome character. We are beginning to learn that it is impossible to feed a baby on fanatical chemical formulae, for they are not prescribed by Nature, which allows latitude within certain limits. We are even beginning to learn that if that were not so there would be no artificially fed babies alive, and possibly very few participants in the St. Louis Congress of Arts and Science.

The inability or reluctance of women to nurse their own infants is a grave matter. From a physical, moral, and socio-political point of view there is only one calamity still graver, that is to refuse to have children at all. It undermines the health of women, makes family life a commercial institute or a desert, depopulates the child world, reduces native Americans to a small minority, and leaves the creation of the future America in the hands of twentieth century foreigners. The human society of the future will have to see to it that no poverty, no cruel labor law, no accident, no luxurious indolence, must interfere with the nursing of infants. I believe in the perfectibility of the physical and moral conditions of the human race. That is why I trust that society will find means to compel able-bodied women to nurse their own infants. Infants are the future citizens of the Republic. Let the Republic see that no harm accrue from the incompetence or unwillingness to nurse. Antiquity did not know of artificial infant-feeding. The first information of its introduction is dated about 1500. Turks, Arabs, Armenians, and Kurds know of no artificial feeding to-day. It takes modern civilization to expose babies to disease and extinction. I know of no political or social question of greater urgency than that of the prevention of the wholesale murder of our infants caused by the withholding of proper nutriment. May nobody, however, feel that all is accomplished when an infant has finally completed his 12 months. Society and family owe more than life — they owe good health, vital resistance, and security against life-long invalidism.

But even willing mothers may have no milk. We require a stronger, healthier race, and one that physically is not on the down grade. The nursing question is a social and economic problem like so many others, like the child-bearing question, that confront modern civilization.

We are building hospitals for the sick of all classes, and insist upon their being superior to the best private residences; asylums for the insane, neuropathics, and drunkards; nurseries and schools for epileptics, cretins, and idiots; refuges for the dying consumptives; and sanatoria for incipient tuberculosis. We are bent upon curing and upon preventing. Do we not begin at the wrong end? We allow consumptives and epileptics to marry and to propagate their own curse. We have no punishment for the syphilitic and the gonorrheic who ruins a woman's life and impairs the human race. Man, however, should see that his kind must not suffer. One half of us should not be destined to watch, and nurse, and support the other half. Human society and the state have to protect themselves by looking out for a healthy, uncontaminated progeny. Laws are required to accomplish this; such laws as will be hated by the epileptic, the consumptive, the syphilitic, and the vicious. No laws ever suited the degenerates against whom they were passed, and it is unfortunate that while health and virtue are as a rule not contagious, disease and vice are so to a high degree.

Modern therapeutics, both hygienic and medicinal, has gained much by the close observation of what is permitted or indicated or required in early age. Since it has become more humane (remember it is hardly a century since Pinel took the chains off the insane in their dungeons, and not more than half a century since I was taught to carry my venesection lancet in my vest pocket for ready use) and more scientific, so that whatever is outside of strict biologic methods is no longer "a system," but downright quackery — the terrible increase of the latter as a world-plague is deemed by rational practitioners and the sensible public an appalling anachronism. It appears that the states of the Union are most anxious (and have been partially successful) to rid themselves of it, while some at least of the nations of Europe are greater sufferers than we. According to the latest statistics, there is one quack to every physician in Bavaria and Saxony; ten quacks in Berlin, with its emperor and other accomplishments, to every forty-six physicians. Its general population has increased since 1879 by 61 %; the number of physicians, 170, 2 %; that of the quacks, 1600 %.

One of the main indications in infant therapeutics is to fight anemia, which is a constant danger in the diseases of the young, for the amount of blood at that age is only one nineteenth of the whole body-weight, while in the adult it is one thirteenth. The newly-born is particularly exposed to an acute anemia. His blood weighs from 200 to 250 grammes. It is overloaded with hemoglobin which is rapidly eliminated, together with the original excess of iron. This lively metabolism renders the infant very amenable to the influence of bacteria, and the large number of acute, sub-acute, or chronic cases of sepsis is the result. Besides, the principal normal food is milk, which contains but little iron. That is why pediatrics is most apt to inculcate the lessons of appropriate posture, so as not to render the brain suddenly anemic, and of proper feeding and of timely stimulation before collapse tells us we are too late, and the dangers of inconsiderate depletion. The experience accumulated in pediatric practice has taught general medicine to use small doses only of potassic chlorate; large doses of strychnine and alcohol in sepsis, of mercuric bichloride in croupous inflammations, of heart stimulants, such as digitalis, when a speedy effect is wanted, of arsenic in nervous diseases, of potassic iodide in meningitis; it has warned practical men of the dangers of chloroform in status lymphaticus;[1] it has modified hydrotherapeutic and balneological practice, and the theories of hardening and strengthening according to periods of life, and to the conditions of previous general health.

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[1] In the meeting of the Society for the Study of Disease in Children, May 27,

The appreciation of electricity as a remedy has been enhanced by obstetricians, pediatrists, and general practitioners. It is but lately that we have been told (P. Strassmann, *Samml. Klin. Vortr.*, 1903, no. 353) that a newly-born and an infant up to the third week are perfectly insensible to very strong electrical currents. The incompetency of mere experimental work, not corrected or guided by practice, cannot find a better illustration, for there is no more powerful remedy for asphyxia and atelectasis than the cautious use of the interrupted or of the broken galvanic current.

The domain of preventive therapeutics expands with the increased knowledge of the causes of disease. That is why immunizing, like curative serums, will play a more beneficent part from year to year, and why the healthy condition of the mucous membrane of the nose, mouth, and pharynx, which I have been advising these forty years as a prevention of diphtheria, has assumed importance in the armamentarium of protection against all sorts of infectious diseases.

Amongst the probabilities of our therapeutical future I also count the prevention of congenital malformations, which, as has been shown, are more numerous than is generally known or presumed, and often the result of intra-uterine inflammation. In a recent publication F. von Winckel (*Samml. Klin. Vortr.*, 1904, no. 373) emphasizes the fact that the general practitioner or the pathologic anatomist sees only a small number, that indeed the majority are buried out of sight, or are preserved in the specimen jars of the obstetrician. The known number of malformations compared with that of the normal newly-born varies from one to thirty-six to one to one hundred and two or more. They are met with in relatively large numbers on the head, face, and neck — altogether in 53.2 % of all the 190 cases of malformation observed in Munich during 20 years. A number of them is the result of heredity, of syphilis, or other influences. How many are or may be the result of consanguineous marriages will have to be learned. In all such cases the treatment of the parents or the prohibition of injurious marriages will have to be insisted upon. The number of those recognized as due to amniotic adhesions or bands is growing from year to year. Kümmel could prove that of 178 cases, 29 were certainly of that nature. External malformations have long been

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1904, Mr. Thompson Walker alluded to the collection of ten cases with status lymphaticus in which death had occurred at the commencement of chloroform administration, or during it, or immediately after the operation. In addition to the usual changes, a hyperplasia of the arteries had been noted, leading to narrowing of the lumen.

ascribed to them; proximal malformations, such as auricular appendices, harelip, anencephalia, cyclopia, flattening of the face, anophthalmia, hereditary polydactylia (Ahlfeldt and Zander, *Virchow's Archiv*, 1891), and lymphangioma of the neck, have been found to be caused by amniotic attachments or filaments. Is it too much to believe that the uterus, whose internal changes, syphilitic or others, are known to be very accessible to local and general medication, should be so influenced by previous treatment that malformations and fetal deaths will become less and less frequent?

The problem of the health and hygiene mainly of the older child refers to more than its food. The *school* question is in the foreground of the study of sanitarians, health departments, physicians, and pedagogues. Its importance is best illustrated by the large convention which was organized in Stuttgart, April, 1904, as an International Congress for School Hygiene. Pediatrists, pedagogues, and statesmen formulated their demands and mapped out future discussions. Rational pediatrics would consider the following questions: Is it reasonable to have the same rule and the same daily sessions for children of eight and perhaps of fifteen years, and for adolescents? Certainly not. The younger the child the shorter should be the session, the longer and more frequent the recesses. There should be no lessons in the afternoon, or only mechanical occupations, such as copying, or light gymnastics. There should be no home lessons.

The problem of overburdening was carefully considered by Lorinser in 1836, and by many since. It deals with the number of subjects taught, the strictness and frequency of official examinations, and should consider the overcrowding of school-rooms. We should try to answer the question whether neuroses are more the result of faulty schooling or of original debility, heredity, underfeeding, lack of sleep, bad domestic conditions, or all these combined. In Berlin schools they have begun to feed the hungry ones regularly with milk and bread. No compulsory education will educate the starving. The child that showed his first symptom of nervousness when a nursling, the child with pavor nocturnus, or that gets up tired in the morning, or suffers from motor hyperesthesia, pointing or amounting to chorea, unless relieved instead of being punished by an uninformed or misanthropic or hysterical teacher, gets old or breaks down before the termination of the school term or of school age. There should be separate classes for the feeble, for those who are mentally strong or weak, or of medium capacity. All of such questions belong to the domain of the child's physician, the physician in general. The office of school physician is relatively new. Whatever we have done in establishing it in

America has been preceded by countries to which we are not in the habit of looking for our models. Bulgaria and Hungary have no schools without physicians. On the other hand, Vienna has none for its 200,000 school-children. It is reported that the aldermen refused to appoint one. One of them objected for the reason that the doctor might be tempted to examine the Vienna lassies too closely. His business would be, and is, to look out for the healthfulness of the school buildings, its lighting, warming, cleanliness, the cleanliness of the children and their health, and that of the teachers. A tubercular teacher is a greater danger to the children than these, who rarely expectorate, to each other. He would take cognizance of the first symptoms of infectious diseases, examine eyes, ears, and teeth, and inquire into chronic constitutional diseases, such as rachitis and scrofula in the youngest pupils. He might undertake anthropometrical measurements and benefit science while aiding his wards. He would be helped in all these endeavors by the teachers, who must learn to pride themselves on the robust health of their pupils, as they now look for the accumulation of knowledge which may be exhibited in public examinations.

They would soon learn, what Christopher demonstrated, that physical development, greater weight, and larger breathing capacity, correspond with increased mental power, joining to this the advice that a physical factor as well as the intellectual one, now entirely relied upon, should be introduced in the grading of pupils. (Charles F. Gardiner and H. W. Hoagland, *Growth and Development of Children in Colorado*, *Transactions*, American Climatological Association, 1903.)

Our knowledge of the physiology and pathology of the *nervous system* of all ages would be defective without lessons derived from the fetus and infant. Amongst the newly-born we have often to deal with arrests of development, such as microcephalus, or with that form of fetal meningitis or of syphilitic alterations of blood-vessels which may terminate in chronic hydrocephalus. When the insufficient development of reflex action in the newly-born up to the fifth or sixth week has passed, the very slow development of inhibition during the first half-year or more, together with the rapid increase of motor and sensitive irritability, explains the frequency of eclampsia and other forms of convulsions. Many of them require, however, an additional disposition, which is afforded either by the normal rapid development of the brain, or the abnormal hyperemia of rachitis. The last twenty-five years have increased our knowledge considerably in many directions. Congenital, premature, complete, or partial ossification of the cranial sutures lead mechanically to idiocy, or paralysis, or epilepsy; it is a consolation, however, to know that the victims of surgical zeal are getting less in number since operators have consented to fear death on the operating-table and thoughtful surgeons have come to the conclusion to leave bad enough alone. In the very young the fragility of the blood-vessels, the lack of coagulability of the blood, the large size of the carotid and vertebral arteries, the frequency of trauma during labor and after birth, the vulnerability of the ear and scalp, contribute to the frequency of nervous diseases, which before the fifth year amounts to 87 % of all the cases of sickness. Rapid exhaustion leads to intracranial emaciation and thrombosis, the so-called hydroencephaloid of gastro-enteritis. The large size and number of the lymph-vessels of the nasal and pharyngeal cavities facilitate the invasion into the nerve centres of infections which show themselves as tubercular meningitis, cerebro-spinal meningitis, and polio-encephalitis, or more so, poliomyelitis, and as chorea of so-called rheumatic — mostly streptococcic — origin. Nose and throat specialists, as well as anatomists, have contributed to our knowledge on these points — another proof of the intimate dependency of all parts of medicine upon one another. Now all these conditions are not limited to early life, but their numerical preponderance at that time is so great that it is easy to understand that general nosology could not advance without the overwhelming number of well-marked cases amongst children. Amongst them are the very numerous cases of epilepsy. They escape statistical accuracy, for many an epileptic infant or child dies before his condition is observed, or diagnosticated; a great many cases of petit mal, vertigo, dreamlike states and somnambulism, fainting, habit-chorea, truancy, imbecility, incompetency, or occasionally wild attacks of mania, or the perversity of incendiarism, or in older children religious delirium, even hysteric spells, are overlooked or perhaps noticed or suspected by nobody but the family physician; or, in the cases of the million poor, by nobody. They are cared for or neglected at home, and the seizure is taken to be an eclamptic attack due to bowels, worms, colds, and teeth, exactly like three hundred years ago.

Of equal importance in this disease to the pediatrist, the pedagogue, the psychiatrist, the judge, the statesman, no matter whether in office or a thoughtful citizen, is the influence of heredity. The old figures of Echeverria, which have been substantiated by a great many observers, tell the whole story. One hundred and thirty-six epileptics had 553 children. Of these, 309 remained alive; 78 (25 %) were epileptic; how many of the 231 that died had some form of epilepsy or would have exhibited it, nobody can tell. He observed a dozen cases in one family. While in his opinion 29.72 % showed a direct inheritance from epileptic parents, Gowers has a percentage of 35, and Spratling, who has lived among epileptics nearly a dozen years, 66.

Epilepsy is acknowledged to be one of the causes of imbecility, or genuine idiocy. In very many instances it should be considered as the coördinate result of congenital or acquired changes in the skull, the brain, and its meninges, and particularly the cortex. In a single idiot institution, that of Langenhagen, 15% to 18% of the 395–668 inmates were epileptic; in another, Dalldorf, 18.5% to 24.3% of 167–344; in a third, Idstein, 36% of 101 (Binswanger, in Nothnagel, *Syst. Path. u. Ther.*, vol. XII, 1310).

Its main causes are central. External irritations, worms, calculi, genital or nasal reflexes, may be occasional proximate causes. But cauterization of the nares, and still more, circumcision, and clitoridectomy prove more the helplessness or recklessness of the attendant than the possibility of a cure. The individual cases of recovery by the removal of clots, bones, or tumors, are great and comforting results, but if epilepsy and its relations are ever to disappear, it is not the knife of the surgeon but the apparatus of human foresight and justice that will accomplish it. Most of the causes of epilepsy are preventable. To that class belong syphilis and alcoholism in various generations, rachitis, tuberculosis, and scrofula, many cases of encephalo-meningitis, and most cases of otitis. A question is attributed to a royal layman, "If preventable, why are they not prevented?" If there is a proof of what Socrates and Kant said, namely, that statesmanship cannot thrive without the physician, it is contained in the necessities of epilepsy. Prevention, preventives, and hygienic, medicinal, and surgical aids have to be invoked, unfortunately with slim results so far.

The influence of hereditary syphilis on the diseases of the nervous system has been studied these twenty years, both by neurologists and pediatrists. Its results are either direct — that means characteristically syphilitic — or metasyphilitic — that means merely degenerative. Hoffmann cured a case of syphilitic epilepsy in a girl of nine years in 1712. Plenk describes convulsions and other nervous symptoms depending on hereditary syphilis, and Nils Rosen de Rosenstein describes the same in 1781. The literature of the latter part of the eighteenth and of the first half of the nineteenth century is silent on that subject, though the cases of affections of the nervous system depending on hereditary syphilis are very frequent (thirteen per cent of all the cases, according to ***Rumpf die Syph. Erk. d. Nervensystems***, 1889). Jullien (*Arch. Gén.*, 1901) reports 206 pregnancies in 43 syphilitic marriages. Of the children, 162 remained alive. Half of them had convulsions or symptoms of meningitis.

According to Nonne (*Die Syph. d. Nervens.*, 1902) hereditary syphilis differs from the acquired form in this — that several parts of the nervous system are affected simultaneously; and that arteritis, meningitis, gummata, and simple sclerosis occur in combination. Simple cerebral meningitis and apoplexies are very rare. Encephalitis is more frequent. Probably spinal diseases are more frequent, according to Gilles de la Tourette, Gasne, Sachs, and others. Tabes dorsalis is not frequent, but may rather depend on an atavistic syphilitic basis; for altogether the nerve syphilis of the second previous generation as a cause of disease in the young is not very rare. (E. Finger, *W. klin. Woch.*, 13, 1900.)

What we call neuroses are not infrequent in infants and children. Neuralgias are not so common as in the adult, but would be more frequently found if sought for. Even adipositas dolorosa has been observed in childhood. Hysteria is by no means rare and its monosymptomatic character, so peculiar to early age, adds to its nosological importance. Its early appearance is of grave import. Its often hereditary origin makes it a serious problem, under-alimentation or ill-nutrition, rachitis and scrofula, frequently connected with and underlying it, may make it dangerous and a fit subject for the study of educators, psychologists, judges, and all those whose direct office it is to study social and socialistic problems. Hysteria is not quite unknown amongst males, though the large majority are females.

Some of the vaso-motor and trophic disturbances are less, others more frequent, in the young than in the adult. Amongst 129 cases of akrosparesthesia there is only one of Frankl Hochwart in a girl of 12 years, and one of Cassirer in a girl of 16. Sclerodermia is met with mostly in mature life, but the cases of Neumann at 13 days, and those of Cruse, Herxheimer, and of Haushalter and Spielmann, who observed two cases in one family, all of them when the infants were only a few weeks old, prove that the same influences which are at work in advanced age, namely, hereditary disposition, neuropathic family influence, low general nutrition, colds, trauma, and so on, may play their rôle in infant life. Nor are infant erythromelalgias numerous. Henoch saw one in a teething infant, Baginsky in a boy of 10, Heimann one in a girl of 13, Graves one in a girl of 16; that means three or four cases below 13 or 16 years of age, out of a number of 65 collected by Cassirer in his monograph. (*Die Vasomotorisch-trophischen Neurosen*, Berlin, 1901.) In half a century I have seen but one that occurred in early age, namely, in a boy of 12, who got well with the loss of two toes. On the other hand, the symmetrical gangrene of Raynaud and acute circumscribed edema of Milton and Quincke, 1882, treated of by Collins in 1892, are by no means relatively rare in infancy and childhood. There are a few cases of the former that occurred in the newly-born. Two I have seen myself. There are those which have been observed at 6 months (Friedel), 9 months (De France), at 15 months (Bjering), at 18 months (Dick). In the year 1889 Morgan collected 93 cases, 13 of which occurred from the second to the fifth, 11 between the fifth and tenth, and 15 between the tenth and twentieth years. Amongst the 168 cases collected by Cassirer, 20 occurred below the fifth, 8 between the fifth and tenth, and 25 between the tenth and twentieth years of life. Like most nervous diseases, these cases had either congenital or acquired causes, amongst which a general neuropathic constitution, and the hereditary influence of alcohol, chlorosis, and anemia are considered prominent. Of acute circumscribed edema, 28 cases are found below nine years of age in Cassirer's collection of 160 cases, one of which at the age of one and a half months is reported by Crozer Griffith, one at three months by Dinckelacker. Again hereditary influence is found powerful. Osler could trace the disease through five generations.

The connection of pediatrics with *psychiatry* is very intimate. Insane children are much more numerous than the statistics of lunatic asylums appear to prove, for there are, for obvious reasons, but few insane children in general institutions. It is only those cases which become absolutely unmanageable at home that are intrusted to or forced upon an asylum. The example of the French, who more than fifty years ago had a division in the Bicêtre for mentally disturbed children, has seldom or not at all been imitated. Thus it happens that though not even a minority of the cases of idiocy become known, its statistics is more readily obtained than that of dementia of early life. Some of its physical causes or accompaniments have been mentioned — asphyxia with its consequences, ossification and asymmetrical shape of the cranium, accidents during infancy and childhood, and neuroses that may be the beginning or proximate causes of graver trouble. Infectious diseases play an important part in the etiology of intellectual disorders. Althaus collected 400 such cases. They were mainly, influenza 113, rheumatism 96, typhoid fever 87, pneumonia 43, variola 41, cholera 19, scarlatina 16, erysipelas 11. In most of the cases there were predisposing elements, such as heredity and previous diseases, or over-exertion of long duration. The overworked brains of school-children were complained of as adjuvant causes of lunacy by Peter Frank as early as 1804. We are as badly off, or worse, a hundred years later.

There is one ailment, however, that appears to hurt children less than it does adolescents or adults, that is masturbation. There are those cases, fortunately few, which depend on cerebral disease, and original degeneracy, but in the large majority of instances masturbation, frequent though it be, has not in the very young the same perils that are attended with it later on when the differentiation of sex has been completed and is recognized. Babies under a year, and children under 8 or 10 will outlive their unfortunate habit, and do not appear to suffer much from its influence. Whatever is said to the contrary is the exaggeration of such as like to revel in horrors. The same exorbitant imagination is exhibited in other statements. What Lombroso and his followers have said of the faulty arrangement of the teeth, prognathic skulls, retracted nose, short and attached lobes of the auricle, as distinct symptoms of mental degeneracy, belongs to that class, and need not always be taken as the positive signs of insane criminality. There is so much poetical exaggeration and word-painting in them that Lombroso and also Krafft-Ebing are the pets of the prurient lay public. In its midst there must be many who are anxious to believe with Lombroso that brown hair and eyes, brachycephalic heads, and a medium size of the body characterizes the insane criminal, if only for the purpose of scanning the hair and eyes and heads of their near friends and their mother-in-law's relatives.

It is certainly not true that, as Lombroso will have it, children are cruel, lazy, lying, thievish, just as little as according to him all savages are like carnivorous animals, and essentially criminal, while others are convinced that by nature they are amiable, like Uncas, and virtuous like Chingacook, and have been rendered savage only by the strenuousness of conquering immigrants. Nor is it true that the idiot brain is merely arrested at a stage similar to the anthropoid, or even saurian development, for it is less arrest of development than the influence of embryonal or fetal disease, beside amniotic anomalies that cause the irregularities of the encephalon.

Amongst the worst causes of idiocy is cretinism, both the endemic and the sporadic. Every cretin is an idiot, not *vice versa.* The endemic could be prevented by state interference which would empty the stricken valleys; the sporadic depends on thyroidism, with or without a shortening of the base of the skull, and is partially curable. The idiotism of cretinism causes a fairly uniform set of symptoms; that which depends on other causes exhibits varieties, though not so many as imbecility, which, too, should not be taken to be the result of a single cause. Osseous and cartilaginous anomalies about the nose are pointed out by William Hill, chronic pharyngitis and nasal polypi by Heller, enlarged tonsils by Kafemann in one third of the cases, some pharyngeal or nasal anomaly in four fifths by Schmid-Monnard. Adenoids are frequently found as complications. Operations to meet all these anomalies have been performed with improvement of the mental condition in some, of the physical in many more, mainly when the anomalies were complications only. But after all we should beware of the belief in miracles and in infallible cures. Mainly the tonsils have been puffed up to be the main causes of many human troubles and their removal a panacea. According to a modern writer it prevents tuberculosis, but the prophet is a little too bold, for he adds that with the exception of himself there are very few able to accomplish it. Defective or diseased brains are frequent in most conditions. The former class allows even imbeciles to excel in some ways. In that class may be found calculating experts, chess-players, or mechanical draughtsmen.

Imbecile persons may be taught sufficiently to prepare for the simple duties of life. There are, however, many transitions between the complete imbecile, the mild imbecile, and the merely slow and dull. That is why the condition is frequently not appreciated. In his school the imbecile child is slightly or considerably behind his class, and the laughing-stock of the rest. As he is intellectually slow, so he is morally perverse or is made to become so. He knows enough to lie and libel, to run away from school, and from truant to become a vagrant. It is true it will not do to declare the imbecile *per se* identical with the typical criminal, but as many of them are illegitimate, or of defective or alcoholic parents, or maltreated at home, or diseased and deformed, they get, by necessity, into conflict with order and the law. Thompson found 218 congenital imbeciles among 943 penitentiary inmates; Knecht, 41 amongst 1214. When the imbecile is once a prisoner his condition is not liable to be noticed on account of the stupefying monotony of his existence.

What is more to be pitied, the fate of the immature or imbecile half-grown child that naturally acts differently from the normal, or the low condition of the state which, instead of procuring separate schools or asylums for the half-witted, has nothing to offer but contumely and prison walls, increasing moral deterioration? There is the stone instead of the bread, of the gospel.

Modern society has commenced, however, to mend old injustices. Every civilized country admits irresponsibility before the law below a certain age, and gradually the mental condition of the criminal is taken into consideration and made the subject of study. But still thousands of children and adolescents are declared criminal before being matured. The establishment of children's courts is one of the things, imperfect though they be, that make us see the promised land from afar. When crime shall be considered an anomaly, either congenital or acquired in childhood, a disease; when society shall cease to insist upon committing a brutality to avenge a brutality; when self-protection shall take the place of revenge, and asylums that of state prisons — then we shall be a human, because humane, society.

Conclusions

Pedology is the science of the young. The young are the future makers and owners of the world. Their physical, intellectual, and moral condition will decide whether the globe shall be more Cossack or more Republican, more criminal or more righteous. For their education and training and capabilities, the physician, mainly the pediatrist, as the representative of medical science and art, should become responsible. Medicine is concerned with the new individual before he is born, while he is being born, and after. Heredity and the health of the pregnant mother are the physician's concern. The regulation of labor laws, factory legislation, and the prohibition of marriages of epileptics, syphilitics, and criminals are some of his preventive measures to secure a promising progeny. To him belongs the watchful care of the production and distribution of foods. He has to guard the school period from sanitary and educational points of view, for heart and muscle and brain are of equal value. It is in infancy and childhood, before the dangerous period of puberty sets in, that the character is formed, altruism inculcated, or criminality fostered. If there be in the commonwealth any man or any class of men with great possibilities and responsibilities it is the physician. It is not enough, however, to work at the individual bedside and in a hospital. In the near or dim future, the pediatrist, the physician, is to sit in and control school boards, health departments, and legislatures. He is the legitimate adviser to the judge and the jury, and a seat for the physician in the councils of the Republic is what the people have a right to demand. Before all that can be accomplished, however, let the individual physician not forget what he owes to the community now. Mainly to the young men amongst us I should say, do not forget your obligations as citizens. When we are told by Lombroso that there is no room in politics for an honest man, I tell you it is time for the physician to participate in politics, never to miss any of his public duties, and thereby make it what sometimes it is reputed not to be in modern life — honorable. A life spent in the service of mankind, be our sphere large or narrow, is well spent. And never stop working. Great results demand great exertions, possibly sacrifices. After all, when everything in science and politics that now is our ideal shall be accomplished while we live or after we shall be gone, we shall still leave to our progeny new problems.

WORKS OF REFERENCE FOR THE DEPARTMENT OF MEDICINE

(Prepared through courtesy of Dr. Hobart A. Hare, Philadelphia)

Abbott's Bacteriology.
Allen's Radiotherapy, Phototherapy and High-Frequency Currents
Bacon on the Ear.
Binnie's Operative Surgery.
Brewer's Surgery.
Chapman's Physiology.
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DEPARTMENT XVIII—TECHNOLOGY

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(*Hall 3, September 20, 2 p. m.*)

CHAIRMAN: CHANCELLOR WINFIELD S. CHAPLIN, Washington University, St. Louis.
SPEAKER: PROFESSOR HENRY T. BOVEY, F. R. S., McGill University, Montreal.

THE FUNDAMENTAL CONCEPTIONS WHICH ENTER INTO TECHNOLOGY

BY HENRY TAYLOR BOVEY

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The Fundamental Conceptions which enter into Technology is a large subject and one which, from its very nature, I cannot hope to treat with completeness. In asking me to undertake its exposition, I assume it was understood that, as a technologist myself, I should naturally speak without the terminology of philosophy — shall I say in an untechnical manner? — that is, from the standpoint of a practical man.

The prevailing characteristic of the eighteenth century has been considered to be the philosophic spirit, while that of the present age is admitted to be the scientific spirit; some even call it the age of the application of science. Is it a sign of a coming reaction that I am asked to speak of what might not inappropriately be called the philosophy of science?

Science, which, at the outset, attacked the more striking facts of the external world, now busies itself with the invisible, the intangible, the inaudible. This line of growth must tend in the direction of stimulating the imagination, and of directing the mind to an investigation of the principles on which sciences are based. Thus we find that science, which at first appeared to be leading away from philosophy, is seemingly leading back to it again, and that we, its followers, have been unwittingly tracing out another of the great circles of truth. However this may be, we have now to consider the conceptions which enter into the most practical of all the sciences, and the one which, of all others, was long supposed to be purely experimental and to require no mental foundations of any kind.

A conception is a thing so subtle, so illusory, that it seems capable of receiving the work of many minds and many generations before it can be said to emerge with any — not to speak of absolute — clearness from the background of thought. Our first efforts to give it a shape bear about the same relation to the complete thought as the first rough tracing might do to a finished statue. Take, for example, the conception of the development of the individual, which is so marked a feature of all modern educational theories. How slowly it has taken shape in the thought of the world! How far are we still from acting in accordance with it! How far from realizing that *power* and not knowledge should be the true aim in education!

Towards the better understanding of technology comparatively little has been done, and that for the very natural reason that the practical has constantly turned aside the attention. The Technologue (to use a word not yet adopted into English) has been described as an intermediary between the savant and the mechanic, translating, as it were, the discoveries of the former into the uses of the latter. Although we may see reason later to modify this view, still, in a certain sense, it is quite true, and the truth of it accounts for the fact that the exponents of practical science have hitherto had little time or inclination to travel with any speed towards the realm of the abstract. Yet much good work has been accomplished. Merz has investigated the scientific spirit with a view to discover its effect on the progress of thought in Europe; Reuleaux has spoken of the evolution of science with especial reference to technology; Anderson, in his Forrest Lecture, has chosen as his subject the relation of science to engineering, and a host of others have discussed before learned societies special aspects of technology chiefly relating to the history of its development during the present century. It is little wonder that such splendid achievements as this history chronicles should so have dazzled our eyes that we have not attempted to inquire too closely into their source To-day, however, we shall try to regard these achievements only as the effects of a cause which we seek to find. We shall restrict our admiration of the constructive ability displayed in a Brooklyn Bridge or a Saint-Gothard tunnel; of the inventive genius shown in a Morse system of telegraphy, or a Bell telephone; of the force of insight and determination which overcame the practical difficulties of the steam-engine or saved its vineyards to France. We shall restrict our admiration, I say, and try to discover the controlling ideas which were common to all, and which impelled the directors of these great enterprises along such apparently diverse paths.

We may notice especially three of these ideas. In the first place, these men must have observed that nature works in no arbitrary manner, but by fixed laws; that while the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night, shall not cease.

Secondly, they must have perceived that, as Reuleaux points out, if these laws could be brought into the right relation with us, or rather, if we could bring ourselves into the right relation with them — into the line of their working — we might hope to be able to gear our small machines to the vast wheel of nature, and make it do for us what we could never do for ourselves.

A recent writer has asked us to recognize in certain inventions of man *extra-organic sense-organs;* to see a projection of the human eye in the telescope and the microscope, which so marvelously extend our vision that it can resolve the misty light of the far-off nebulae into suns, or discern in a clod of clay a world of wonder; to hear in the telegraph and the telephone the tones of the human voice so intensified as to reach round the world, and in the printed page the silent voices of long past generations; to know the express train and the ocean liner as extensions of our locomotor-mechanism; and to discover in a tool or a lever the human arm grown strong enough to perform seeming miracles.

Thirdly, these master-minds must have realized that in the study of the laws of nature, and in the attempt to put ourselves into touch with them, there would certainly be revealed more and more of what seem to be the infinite possibilities of our environment.

In almost every endeavor to explain the nature of observed phenomena, fresh and important facts emerge which in their turn call for explanation. This is true, for instance, of the investigations in radio-activity now being carried out by Professor Rutherford, in which the deductions are so novel and startling that it would have been impossible beforehand to have made any prediction as to their character. Again, what a vista has already been opened up by the interaction of the sciences! What a great development, for example, has taken place in electro-metallurgy, due entirely to the processes made possible by a combination of physics and chemistry, and based upon Faraday's well-known law of electrolysis!

The first and second of these conceptions, namely, that law is a fixed thing, and that if we and our work could be brought into the right relationship with the laws of nature, they would expend their mighty force in our service, make possible a *process* under the control of man, a process which, while having many intermediate objects, has always the same goal. Thus we may primarily study the steam engine with a view to a knowledge of its mechanism, while our ultimate aim, if we are to work with complete success, must be so to design its several parts that it may lend itself to the power of steam with the least possible resistance.

We may conceive of a law of nature as a fixed thing, a Niagara of force; we want to construct a wheel which shall receive its impact and turn its water into fire. Nothing can change or improve the law; the only thing we can do is to make ourselves familiar with it, which may be done either by watching its operation in nature, or by causing it, as it were, to display itself before us — bringing together the materials whose interaction it is our purpose to investigate. This we call making an experiment, and it has now become the usual method of studying the laws of nature. To this fact, indeed, must be attributed much of the rapid progress of modern science, as we have no need any longer to wait, as did our ancestors, for nature periodically to marshal her forces and cause them to defile before us.

This, in general, is all we can do with our environment. What can we do with ourselves?

In order to study to advantage we must get into line with the laws of the mind, remembering that they are, equally with heat and electricity, the laws of nature. We must make the laws of the mind work for us instead of against us, just as we are seeking to do with the forces external to us.

We find that to bring us into contact with the outer world nature has given us the five senses, and the wonder is with how small a use of them people manage to get through their lives. The reason is, perhaps, that these senses only present facts to us, and facts, although necessary to thought, require, like other raw materials, to be worked up before they give us ordered knowledge.

We also find that the apprehension of a fact by the mind requires the exercise of the power of observation. This presupposes sensibility both of the external organ and of the brain centres, and also a certain amount of will-power which prevents the observation from being a mere photographic reproduction of the external world. The observations we speak of must be of a special character. They should be minute like those of Hunter in his study of a deer's horns; they should be accurate like those which led Adams and Leverrier to the simultaneous discovery of Neptune, and, above all, they should be selective, that is, if we are following up a special point, we should be able to fasten, as it were, on the fact which throws light on the question at issue, remembering that it is not always or even usually the feature most prominent which will put us on the track of the discovery of true connections, but more often some small detail which the ordinary person passes by unheeding. For instance, take the case of Becquerel when examining a definite point suggested by the discovery of the Röntgen rays. At that time it was thought that the phosphorescence produced in a vacuum tube was in some way connected with the excitation of X-rays. Becquerel, therefore, examined bodies which were phosphorescent under ordinary light, to determine if they gave out rays of a similar character. On a certain dull day he happened to leave a photographic plate exposed over uranium, and to his surprise he found that a marked photographic impression was produced. Knowing that the phosphorescent light from the uranium compound persists for only a short time, he was able to draw conclusions which proved to be the commencement of the now great and important investigation into radio-activity.

Observation, as commonly used, seems to mean to see with attention. It therefore involves concentration, or the focusing of the whole force of the mind on one point for an appreciable moment of time. As soon as concentration takes place, a process of analysis begins, and we pass through the perception of likeness and difference to classification and then to generalization, by which we fit observed facts into their proper places in the scheme of nature, gathering up the new with the old into a larger and larger synthesis. Memory now comes into play to retain what we have gained; and a new impulse to gather new facts, as well as, sometimes, a fresh point of view, we gain from the contact of the new with the old and the arousing of the power of deduction.

Further, we must not overlook what is really a fact of the utmost importance — that the cultivation of observation by the sense of touch and the use of the hand as an instrument, together with the possibility of making experiments which must be carried out by the hand, have led to what might be called a discovery, namely, that the training of the hand actually stimulates the brain centres. This has given to manual training its true value.

By this *process*, in the first place, of studying the laws of nature, either as they are presented to us in the natural course of events, or as we may induce them to display themselves before us in experiments; and, secondly, by studying them with all possible reference to the laws of the mind, including those of the interaction of the hand and the brain, we attain to that knowledge of our environment and to that plane of capacity in ourselves which are necessary preliminaries to the bringing of the powers of nature under our control in the interests of humanity.

What is the indispensable step which often intervenes, which, untaken, makes it still necessary that we should call so much of our knowledge by the name of pure science? For how many centuries had sticks been rubbed together to produce fire before Rumford, while superintending the boring of cannon in the Arsenal Works at Munich, hit upon the true explanation of what becomes of work spent in friction? Or, as Lamb humorously puts the case, in discussing the origin of the custom of eating roasted instead of raw meat, "in process of time, says my manuscript, a sage arose, like our own Locke, who made a discovery, that the flesh of swine, or indeed of any other animal, might be cooked (*burnt*, as they called it) without the necessity of consuming a whole house to dress it. Then first began the rude form of a gridiron. Roasting by the string, or spit, came in a century or two later, I forget in whose dynasty. By such slow degrees, concludes the manuscript, do the most useful, and seemingly the most obvious arts, make their way among mankind." The veil which hid the prospect, once dropped, is not our natural exclamation, "Why did we not see that before?" What, then, is the necessary step? Is it not the exercise of just that quality which the scientific man has been blamed, and often with too much reason, for neglecting? — the divine gift of imagination, which

> "bodies forth the forms of things unknown."

In his *Defence of Poetry*, Shelley points out the evil effects "which must ever flow from an unmitigated exercise of the calculating faculty," and says, "whilst the mechanic abridges, and the political economist combines labour, let them beware that their speculations, for want of correspondence with those first principles which belong to the imagination, do not tend . . . to exasperate at once the extremes of luxury and want."

Out of such conceptions as these two, by the process just described, the science which has received the descriptive title of applied science and the general title of technology, has grown up, but almost unconsciously, for, as a matter of fact, it has arisen far more from practical necessity than from thought-out schemes. We can see that it has a twofold nature corresponding to the process referred to.

First, we can learn by specialized study how to understand and apply the principles of mechanics — which is coming to be regarded by some authors as the primary all-embracing science — to the construction of works of utility of every kind. We find this conception distinctly recognized in the founding at Harvard of the Rumford Professorship in 1816. In his will, Count Rumford reserves certain annuities "for the purpose of founding a new institution and professorship, in order to teach by regular courses of academical and public lectures, accompanied with proper experiments, the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness and well-being of society."

Secondly, we can train the mind of the student to work easily along lines of scientific thought; in fact, we can do much to form the scientific mind.

It will now be seen that, so far as we have considered it, technology is really a process of education — a secondary science — a process which has been described by Ellis as an entire system of education by new methods to new uses. He tells us, at the same time, that the first use of the word technology, apparently, was made in connection with the professorship just mentioned, in that Dr. Bigelow, who, for ten years, held it with marked ability and success, published his lectures under the name of the *Elements of Technology.*

We find, however, that technology, as now taught, embraces a third department of a completely different character, and one which has arisen out of the working of the third conception to which I have called attention, namely, that in the attempt to utilize the natural laws, there would certainly be revealed more and more of the infinite possibilities of our environment.

So indeed it has proved. It happens that certain investigations into the chemical and physical properties of matter, into the dynamics of steam, electricity, etc., have been made by the engineer rather than by the physicist and the chemist, because these investigations have been required by the practical work of the engineer, and because they have sometimes to be carried out on a scale inconsistent with the more delicate experiments which are the chief occupation of the physical laboratory. So it has come to pass, as a matter of convenience mainly, that engineering, besides being a profession, has been made directly responsible for certain scientific work, and may in this light be looked upon as containing within itself a pure science.

Numerous examples might be quoted as illustrating this statement from any good engineering laboratory, and I will just refer to one or two which I have taken from our own experience at McGill University. Callendar and Nicolson, with the platinum thermometer and ordinary steam-engine, were able to deduce laws of the utmost importance relating to the cylinder condensation of steam. The experiments of Adams and Nicolson, and subsequently of Adams and Coker, have thrown new light on the flow of rock-masses under high pressures and temperatures, and further developments may be hoped for, as generous provision for the purpose has been made by the Carnegie Institute. By means of specially designed extensometers it has been possible to study, within the limits of elasticity, the lines of stress in beams under transverse loads, and much progress has been made in the solution of many hydraulic problems, notably in the determination of coefficients and the critical velocity.

This department of technology, which is daily assuming more importance, has hitherto been little emphasized, and it naturally brings us to consider the distinction between pure and applied science and also the definition of the place we must assign to technology in the general scheme of knowledge, a definition involving the proper classification of science in the widest sense, a subject which has occupied the attention of many learned minds.

Our very word *science* itself, that is, knowledge so systematized that prediction and verification by measurement, experiment, observation, etc., are possible, is in Germany limited by the name of *exact* science, and is included in a larger idea, *Wissenschaft*, which seems to embrace ordered knowledge of every kind; for example, the accepted principles which govern the search for historical and philosophical truth. The German idea of *Wissenschaft* includes at once the highest aims of the "exact, the historical, and the philosophical lines of thought." "That superior kind of knowledge, dignified by the title of Science, must," says one writer, "have generality as opposed to particularity, system as opposed to random arrangement, verification as opposed to looseness of assumption."

In view of what has gone before, there is no need, I imagine, further to substantiate the claims of technology to a rank amongst the sciences. We have tried to show that its material is scientific, that it is itself in all departments a scientific method of dealing with nature, and, in one department, an actual investigation into nature; but we shall see that its place in a general classification of science is rather a composite one.

Pure science has been defined as "the knowledge of . . . powers, causes, or laws, considered apart or as pure from all applications." It involves a research into facts by which we learn to understand their nature and to recognize their laws, and its description naturally includes a history of the facts or experiments by means of which it has been made manifest. In one sense every one of these experiments is an application of already known laws of science to something of the nature of a machine — a case exactly parallel, in outward seeming, with what is done in the ordinary departments of technology. Yet, with a true instinct, it is not called technology, and why? Because the *aim* is different. Even if the ultimate aim be utility, it is not primarily so. The first and immediate aim is to subserve no practical purpose, but to dig deep into nature's garden and find the roots which, down in the dark, are working out their wonders.

These experiments may be called *applications of pure science*, but we will not give them the name of applied science or technology, which clearly involves the idea of utility. Whether this is necessarily a higher or a lower ideal, we will not at present consider, for we have shown that we have a claim to both ideals; but we will simply admit, nay more we will emphasize the fact, that the technologist, in the ordinary sense, wants to know about the heat of the sun in order that he might drive its chariot with greater success than Phaethon of old. It is not *knowledge* but *power* which is his ultimate aim.

Even in the department of pure science, to which we have referred as the third department of technology, the idea of utility is more prominent than it ordinarily is in the laboratories of pure science, though still in its highest form, and acting rather as an incentive to begin the work than affecting the manner of carrying it out. For instance, the strong desire to eliminate the errors caused by the sensitiveness of metals to variations of temperature has prompted the effort to find a remedy, which has recently resulted in the use of a definite combination of nickel and steel, a material practically insensitive to temperature changes.

The idea of *utility* seems to be the real key to the distinction between pure science and technology.

We find technology variously described as the science of the industrial arts; as the application of scientifically obtained facts and laws in one or more departments to some practical end, which end rules the selection and arrangement of the whole, as, for instance, in the practical sciences of navigation, engineering, and medicine. Again, applied science is defined as a knowledge of facts, events, and phenomena as explained, accounted for, or produced by powers, causes, and laws.

We see that when laws are attached to facts, whether in nature or experiment, for the purpose of explanation merely, we call it pure science, but when laws are attached to facts with an idea of utility in art, manufacture, or in the general service of humanity, we call it applied science or technology. In the first case, the fact is viewed as an instance of the law; in the second, the fact itself is the important thing. Therefore, the distinction between pure and applied science seems to be largely one of purpose; if our purpose is to establish a law we call it pure science, if our purpose is to establish a fact we call it applied science.

We see, therefore, that technology, while in one department a pure science, investigating the laws which govern, for example, the strength of structures both as dependent on material and form, or, in general, any problem arising out of the artificial working-up of natural products, is, in the main, to be called an applied science, and is in fact so described. I can find no essential difference between the use of the two terms "applied science" and "technology," as they are ordinarily employed at present, and scarcely a case in which either of them could not be used. A notable exception is the science of medicine, which is, strictly speaking, an applied science, but which is never described as technology, perhaps foreshadowing a more distinct specialization in the use of the term technology, so that it may indicate only the science of man's makings and not the science of man's doings. The scope of technology, even as thus defined, is, perhaps, its most striking characteristic.

The endless range of knowledge, opened up by an attempt to apply even the known laws of nature to the limitless array of facts, is at once apparent, even if we say nothing of facing the new problems arising in the process. Our material is evidently the whole world, with all the giant forces impelling it on its yearly circuit, lighting, heating, and supporting its myriad forms of life and ruling their motion and their rest.

Where shall we find a guide in this complexity? How shall we choose between necessary and unnecessary knowledge? In theory it seems impossible to draw any line, and one never knows at what moment a new department may become essential; but, in practice, this very possibility has suggested the course which has been followed, namely, the attempt that has been made to gain a knowledge of those laws which *up to the present time* have been adapted to practical needs. As more of these laws are utilized they, too, will be incorporated, and the limitations of the human mind must then be provided for, in a greater degree than is the case at present, by a scheme of options which will allow each individual to use as his *material* mainly the special knowledge that he will require in the department of technology chosen as his particular profession, and which will compel him to know of the other departments only enough to fit this into its right place in the general scheme.

Such a system of options is, fortunately, feasible by reason of the fact that the mental powers, trained to work scientifically in a given direction, can afterwards be turned to other objects. At least this is the case when the *method* of working is given the first importance, as then only is it possible to form the scientific mind.

If we examine the best modern schools of technology we find that the curriculum contains departments founded on the conceptions with which we have been dealing. We notice,

First, a study of selected laws of nature (*i. e.*, those which have already been applied to practical purposes);

(*a*) as seen in nature;

(*b*) as seen in examples and descriptions of the means by which they have been utilized. This corresponds to learning by experiment, and includes especially the study of all types of machinery, implements, and instruments.

Secondly, a distinct aim to train the mind of the student in accordance with the laws of the mind.

This is not usually done theoretically, *i. e.*, by any inquiry into the laws of the mind, but practically, *i. e.*, by causing the student to learn some particular form of industrial art in a scientific manner.

Thirdly, a distinct desire to encourage,

(*a*) research into the nature of the practical facts essential to any art, with a view to finding out reasons for the same in the *known* laws of nature, thereby giving workmen the opportunity to work intelligently;

(*b*) original research into the problems arising out of industrial processes, with a view to finding out unknown laws of nature, and especially those which must be investigated on a large scale.

We may observe that this classification includes in the *third* division a kind of research, (*a*), which, though not exactly pure science, as it does not seek for unknown laws but only for known laws which will fit a particular case, yet partakes of the same nature as far as the action of the mind is concerned. It is practically useful and necessary as a part of technology, because it supplies to the workers in any art the fundamental reasons which justify the employment of a certain procedure (whether such procedure has been developed by practical experiment or whether it has been developed as a result of theoretical research). This search for causes will naturally increase in importance with the growth of knowledge as to the scientific carrying out of any art, or, in other words, as trades and arts tend to become more scientific.

In practice it is found that foremen, educated in a knowledge of fundamental laws as well as in scientific processes, are far more valuable, and that the workmen also will be all the better, for whatever knowledge of this kind can be given them. Numbers of firms and corporations are now acting on this principle, some even refusing to accept a messenger-boy unless he has passed through a high school.

Further, this training, which enables a worker to recognize essential principles, has the great advantage of showing to the worker in what direction it is possible to make advances and improvements and — no less important a matter — in what direction progress is impossible. The history of invention will emphasize the truth of this statement. How much time and brains, for instance, have been wasted in devising mechanism which involves the fallacy of perpetual motion!

We notice also that, in the second department, the classification includes instruction in the scientific process of carrying out any art required by a student for his future work. In any true university this practically useful plan is made to subserve the end of mental development in the student. This department naturally takes up a great deal of space in an institution, as there may be almost as many options as there are students. Partly for this reason, partly because it is the easiest end at which to begin a technical school, and partly because it appeals most strongly to the non-university man, as being apparently a short cut to success, it is not infrequently *all* that is understood by technology, and is *all* that is directly included in its definition as the *science of the industrial arts.* This scientific instruction in the industrial arts may be said to have been the beginning of technology, and where it has been over-emphasized, it has given apparent justification to the idea (of which there is still a survival) that the subject is not necessarily scientific in any wide sense, and that the practical training of workers is more important than the theoretical.

Technology may be called the child of science on the one hand, and of industrial progress on the other; therefore we must not be surprised to find a very curious blending of the spirit of both in an institute of technology.

We can do exactly the same thing at different times with a different, even with an opposite motive, but though the same thing is produced externally, the result on the mind of the student is, in each case, the result of the inner motive. What happens depends, as it were, on the point upon which the stress is laid. Wherever the spirit of science prevails, we are on the lookout for phenomena which may lead us to a better understanding of a known law, or to a knowledge of some hitherto unknown law of nature. Wherever the spirit merely of industrial progress prevails, we are on the lookout for some adaptations of our machines or processes which may add to the chances of commercial advantage. In the former case, while we learn the best, because the scientific, method of carrying out an art, we put at the same time the real emphasis on producing the scientific man. In the latter case you produce merely an intelligent handicraftsman, whose very highest aim is to improve his art — by no means an ignoble end, but one which might easily be ennobled, and one which may and often does defeat its own purpose — for the true scientific spirit is also a spirit of prophecy, and if you do not succeed in producing it, those things which might have been to you a new revelation will lie by your side unperceived. Merz likens Bacon to "one who inspects a large and newly discovered land, laying plans for the development of its resources and the gathering of its riches."

In the fact of scientific foresight is found a strong practical argument for curbing the impatience to acquire the training requisite for success in a practical profession — the readiness to sacrifice a more remote to a more immediate end. This impatience is still so great as to cause a serious danger that our technical schools may be tempted to give a purely professional training, or that professionalism may become overwhelmingly strong in them, and threatens to introduce, into even our common schools, a far too soon begun specialization.

That this danger exists is one reason why it is true, and probably always will be, that the scientific spirit is relatively more often produced in the students of pure science than in the students of applied science, but note that this is only relatively true. Other things must be considered. Where you can get one man to devote himself to pure science, you can find a thousand to fill the ranks of practical workers, so that you greatly multiply the actual chances of discovering the why and the wherefore of things, and, at the same time, you secure the enthusiasm derived from numbers. Also besides the mere increase of chances arising from larger numbers, and the immediate effect of numbers, we can claim for the workers in applied science, under the *best* conditions,as remarkable a development of the scientific spirit as has ever been recorded in the annals of pure science. Take, for example, the great French chemist and naturalist, Pasteur, who "has been able," as Ray Lankester justly says, "not simply to pursue a rigid path of investigation dictated by the logical or natural connection of the phenomena investigated, but deliberately to select for inquiry matters of the most profound importance to the community, and to bring his inquiries to a successful practical issue in a large number of instances. . . . The discoveries made by this remarkable man would have rendered him, had he patented their application and disposed of them according to commercial principles, the richest man in the world. They represent a gain of some millions sterling annually to the community."

Moreover, we must remember that what we have called professionalism, though limited to a sphere which appeals to our individual interest, is, after all, in part of its nature, very closely akin to the scientific spirit — inasmuch as it seeks for truth, and is often imbued with the spirit which would spend itself in the effort to achieve honest work, in the joy of overcoming, in the patient performance of duty, or in the search for what will bring honor to the profession. Therefore, in contrasting the spirit of professionalism with the scientific spirit, it is rather the element in professionalism that we may call commercialism which we wish to avoid — the way of estimating values by money value and of measuring our interests by dollars and cents.

Further, we cannot afford to condemn even commercialism in a wholesale manner, as is often done. We are led to look for the element of real value which must be there, when we find, for instance, the last India budget pointing with satisfaction to the great increase in bank deposits in spite of plague and famine, and when we find, in general, that we are always able, to a certain extent, to measure any nation's progress by its increase in riches.

Let us notice, however, that the purely scientific man contributes greatly to the world's wealth, but seldom to his own, and has to be supported by a world which knows the value of his work and makes an appreciative *entourage*. Notice, also, that the study of commercial methods is distinctly good as opposed to waste, being quite necessary to the study of economics, which is the application of philosophical and scientific principles to the conduct of life — a kind of final aim of the general application of science to life. To know how to live and conquer our environment financially, in a manner easy enough to leave some margin for intellectual advancement, seems to be a necessary condition of living on a high plane. True, one can have plain living and high thinking, but when it comes to sordid living, when the food is perhaps too little to feed the brain, or even when every scrap of energy is used up in providing for material wants, then indeed the wings of the imagination are clipped and the eagle becomes a barnyard fowl.

If, then, this commercialism has so much that is good and necessary, why should we look upon it as a danger? Because, like fire, it is a good servant, but a bad master; because, in this world, we must look upward, or with level eyes, or downward. We feel instinctively that true scientific thought is an *aspiration*, that a wise economy or management, a taking far-seeing advantage of circumstances, or any honorable making of money, especially for unselfish purposes, is practical common sense, and is helpful in, as it were, buying time in which we may rise to higher things. On the other hand, we feel no less that if we turn the making of money into a goal in itself, the road to it is beset with the pitfalls of greed, selfishness, and dishonor, and that the looking at it thus, or as the chief standard by which to measure values, is quite unworthy of our higher nature. "What lovely puppies!" exclaimed the child. "A hundred dollars' worth of dogs," remarked the lad, who was trying to reach too quickly the time when the glory of dawn melts into the light of common day.

On these grounds we feel that any teaching that allows commercialism to become too important a factor is fraught with danger. That we speak of it not as an evil, but as a danger, suggests a reason why it is not shunned with more care. It is only a risk, and I am afraid that, over-confident in the steadiness of our heads, we seldom mind skirting moral precipices, but in a scientific institution, at least, we ought steadily to build up the invisible moral ideal.

Risk is a conception distinctly opposed to any science seeking after absolute knowledge, and should be as far as possible discouraged, whatever legitimacy there may be in it being replaced by a keener foresight. If we deal with risks at all, it should be in a scientific way, calculating their amount and providing for them, and we should certainly practice what we preach, estimating with care the danger of commercialism, and deciding whether it would not be better to avoid it, lest we be confronted with the necessity of providing a counterpoise for which a technical institute offers no adequate material.

It may be said that this is a side issue, and not a fundamental conception, but our assumptions are always greater than our conscious knowledge, and, in one sense, there are no side issues. No truly scientific man can be blind to the position of his immediate object in the general scheme of things, and the more broad-minded he is the more careful will he be that, as he moves along, he is not stirring up forces for evil; more, he will be *positive* in his effort, and will try to see that it is tending to produce a man whose work shall be worthy of his own nature.

All moral issues, which have been often used in support of the idea of the new technical education, are, in the same sense, side issues. A technical school is not, and cannot be, primarily a school of morals; but even men, sufficiently careless about their own standard of life, are glad enough to encourage and cultivate in others that stability of conduct which is the best bulwark of a democratic state. If we consider the manner in which any moral effect may be looked for, as a result of technical training, we shall see that the process must be something of the following nature. The inner eye, which sees truth, is necessarily aided by the immediate detection of errors in form, or in the nice adjustment of outward things, and the consequent emphasis which is laid upon the value of accuracy. We cannot take the first step towards a virtue until we see it clearly, and, therefore, whatever magnifies it makes that step more possible. Again, we may reflect that the enforced yet pleasant exercise of a virtue may do much to make it agreeable, and may diminish any natural opposition to it which may happen to exist. Further, still, we may go, and assert that the will itself may be, and is, cultivated in the overcoming of obstacles, and, therefore, may be made the more powerful instrument of an awakened and a holy purpose — for deep down beyond all this, we come to the place where we are forced to admit that we have reached the limit of human effort, to the place where the wise will lift up "hands of faith." No science can teach a *love* of truth which shall be strong enough to conquer life. Yet, within its limits, in common with all true scientific teaching, and perhaps in a larger measure proportionate to its appeal to a larger *clientèle*, technology may lay claim to produce moral strength, truth, and manliness.

Nor is this all by any means. Technology has been exalted as the spring of civilization, and it is, and not only or merely because the promoters of utility increase the ease of life, "make space and give time," and so broaden our mental horizon, but also because in the contest with the earthly and the sensual it is no small matter to be reinforced by the widespread existence of intellectual tastes, and because the patient waiting on nature, often so necessary in scientific work, tends to produce self-restraint. To self-restraint and true temperance we must look to save our civilization from passing into rottenness, as has been the fate of many another, which, dahlia-like, has blossomed only to turn into a sodden mass, because, perhaps, it has not recognized the truth that it is of no use at all to *refine* the vices of the state, that the plow, which uproots the evil weeds without mercy, must prepare the way for the waving grain and the fruitful harvest of a true civilization. We might go on — we might call attention to the self-sacrifice which often leads the man of pure science and surely, not seldom, the true technologist, to count his life well lost in the service of truth. Nor in this busy practical age must we forget that, if we choose, we can make each obstacle overcome, not a step from which, like a child in play, we can leap back to our former position, but a point of vantage from which we can scale,

> "By slow degrees, by more and more,
> The cloudy summits of our time."

There is one subject on which I should like to say a word, one that is generally used as a *contrast* to technology, namely, "fine art," or the science of beauty, the beautiful being regarded as the antithesis of the useful. I cannot feel content so to express the relation between the two.

Have we not already noticed that the inspiration of genius, no less in science than in art, requires the imagination as its instrument, and can only express itself in terms of its language? Also, has not one of the greatest writers on the science of the beautiful called our attention to the fact that beauty without strength and truth is a sham? No, there can be here no true antithesis. The power of seeing the abstract must be much the same mental power, to whatever subject it is applied, and whether it discovers ideal truth or ideal beauty, it matters little; the great thing is to feel the Soul of things at all, and not to be only capable of seeing with a surface realism which thinks nothing worth discussing unless it can be handled.

In practice, however, we still find a difficulty. In the early stages of technological education, drawing is recognized to be the foundation of the industrial as well as of the fine arts, but later, an apparently inevitable specialization differentiates between the two, and, except in the one department of architecture, beauty and the science of beauty have been largely ignored by the new education.

Is it really necessary to be ugly in order to be useful? Can we not lift and store our grain without disfiguring our most beautiful views? Must we strip our great forest of trees and make them into bare poles from which to swing our electric wires? Should it be possible to describe any human habitations as packing-boxes pierced with holes? Is it *really* a useful purpose which would take for any common end the glorious redwood forests, planted before the Christian era, "for the service of man" indeed, but for what service — to build him a house — to kindle him a fire — or to waken his soul to a knowledge of its own value?

Here, then, is not a danger to be guarded against, but a want to be supplied. We need the imagination in the highest departments of technology, but there is at present no distinct training for it, and there should be, if only to help a man to realize the unity of his own mental being and the mighty unity of Nature, which could give us a type of the fixity of law in the rainbow, of all colors the most beautiful and ephemeral, of all forms the strongest, throwing across the clouds, still black with threatening, its perfect arch, —

> "A glorious thing that dauntless, deathless,
> Sprang across them and stood steady."

SECTION A—CIVIL ENGINEERING

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(*Hall* 10, *September* 21, 10 *a. m.*)

CHAIRMAN: PROFESSOR WILLIAM H. BURR, Columbia University.
SPEAKERS: DR. J. A. L. WADDELL, Consulting Engineer, Kansas City.
MR. LEWIS M. HAUPT, Consulting Engineer, Philadelphia.

THE RELATIONS OF CIVIL ENGINEERING TO OTHER BRANCHES OF SCIENCE

BY JOHN ALEXANDER LOW WADDELL

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THE topic set for this address is "The Relations of Civil Engineering to Other Branches of Science." In its broad sense civil engineering includes all branches of engineering except, perhaps, the military. This is its scope as recognized by two of the highest authorities, viz., the American Society of Civil Engineers and the Institution of Civil Engineers of Great Britain; for these two societies of *civil* engineers admit to their ranks members of all branches of engineering. It is evident, though, from a perusal of the Programme of this Congress that the Organizing Committee intended to use the term in a restricted sense, because it has arranged for addresses on mechanical, electrical, and mining engineering. But what are the proper restrictions of the term is, up to the present time, a matter of individual opinion, no authority having as yet attempted definitely to divide engineering work among the various branches of the profession. To do so would, indeed, be a most difficult undertaking; for not only do all large constructions involve several branches of engineering, but also the profession is constantly being more minutely divided and subdivided. For instance, there are recognized to-day by the general public, if not formally by the profession, the specialties of architectural, bridge, chemical, electrical, harbor, highway, hydraulic, landscape, marine, mechanical, metallurgical, mining, municipal, railroad, and sanitary engineering, and possibly other divisions; and the end is not yet, for the tendency of modern times in all walks of life is to specialize.

Between Tredgold's broad definition of civil engineering, which includes substantially all the applied sciences that relate to construction, and the absurdly narrow definition which certain engineers have lately been endeavoring to establish during the course of a somewhat animated discussion, and which would confine civil engineering to dealing with stationary structures only, there must be some method of limitation that will recognize the modern tendency toward specialization without reducing the honored profession of civil engineering to a mere subdivision of applied mechanical science.

Without questioning in any way the correctness of the Tredgold definition, civil engineering will be assumed, for the purposes of this address, to include the design and construction of bridges; extensive and difficult foundations; tunneling; retaining-walls, sea-walls, and other heavy masonry; viaducts; wharves; piers; docks; river improvement; harbors and waterways; water-supply; sewerage; filtration; treatment of refuse; highway construction; canals; irrigation works; dams; geodetic work; surveying; railways (both steam and electric); gas-works; manufacturing plants; the general design and construction of plants for the production of power (steam, electric, hydraulic, and gaseous); the general design and construction of cranes, cable-ways, breakers, and other mining structures; the heavier structural features of office buildings and other large buildings that carry heavy loads; the general problems of transportation, quarrying, and the handling of heavy materials; and all designing and construction of a similar nature.

In contradistinction, mechanical engineering should include the design and construction of steam engines, machine tools, locomotives, hoisting- and conveying-machinery, cranes of the usual types, rolling-mill machinery, blast-furnace machinery, and, in fact, all machinery which is designed for purely manufacturing purposes.

Electrical engineering should include all essentially electrical work, such as the designing, construction, and operation of telephone and telegraph lines; electric-light plants; dynamos; motors; switchboards; wiring; electric devices of all kinds; transmission lines; cables (both marine and land); and storage batteries.

Mining engineering should include all underground mining work; means for handling the products of mines; roasting, smelting, milling, stamping, and concentrating of ores; drainage and ventilation of mines; disposal of mine refuse; and similar problems.

It is impracticable to draw hard-and-fast lines between the various branches of engineering, because, as before indicated, nearly all large constructions involve several specialties; consequently no specialist can confine his attention to a single line of work to the exclusion of all other lines. For instance, the bridge engineer encounters mechanical and electrical engineering problems in designing movable bridges; railroading in approaches to bridges; river improvement in the protection of piers and abutments; highway construction in the pavement of wagon bridges; architecture in the machinery houses of swing spans; hydraulic engineering in guarding bridges against fire; and chemistry and metallurgy in testing materials. The railroad engineer encounters architecture and structural engineering in depots, roundhouses, and other buildings; hydraulic problems in pumping-plants and bank protection; mechanical engineering in interlocking plants; and electrical engineering in repair-shop machinery. The mining engineer invades the field of mechanical and electrical engineering in his hoisting, ventilating, and transporting machinery; deals with civil engineering in his surveys; and encounters chemistry and metallurgy in testing ores. Similarly it might be shown that all branches of engineering overlap each other and are interdependent.

It was the general opinion among scientists not many years ago that engineering was neither a science nor a profession, but merely a trade or business; and even to-day there are a few learned men who hold to this notion — some of them, *mirabile dictu*, being engineers; but that such a view is entirely erroneous is now commonly conceded. He is an ill-informed man who to-day will deny that civil engineering has become one of the learned professions. Its advances in the last quarter of a century have been truly gigantic and unprecedented in the annals of professional development. It certainly can justly lay claim to being the veritable profession of progress; for the larger portion of the immense material advancement of the world during the last century is due primarily and preëminently to its engineers.

It must be confessed that half a century ago engineering was little better than a trade, but by degrees it advanced into an art, and to-day, in its higher branches at least, it is certainly a science and one of the principal sciences.

The sciences may be divided into two main groups, viz., "Pure Sciences" and "Applied Sciences."

The "Pure Sciences" include:

(1) Those sciences which deal with numbers and the three dimensions in space, the line, the surface, and the volume, or in other words "Mathematics."

(2) Those sciences which deal with inorganic matter, its origin,

structure, metamorphoses, and properties; such as geology, petrology, chemistry, physics, mineralogy, geography, and astronomy.

(3) Those sciences which deal with the laws, structure, and life of organic matter; such as botany, zoölogy, entomology, anatomy, physiology, and anthropology.

(4) The social sciences; such as political economy, sociology, philosophy, history, psychology, politics, jurisprudence, education, and religion.

"Applied Sciences" include:

(1) Those which relate to the growth and health of organic matter; such as medicine, surgery, dentistry, hygiene, agriculture, floriculture, and horticulture.

(2) Those which deal with the transformation of forces and inorganic matter, viz., the various lines of engineering,—civil, mechanical, electrical, mining, marine, chemical, metallurgical, architectural, etc.

(3) Those which relate to economics; such as industrial organizations and manufactures, transportation, commerce, exchange, and insurance.

Some writers make no distinction between the terms "Political Economy" and "Economics," but in this address they are divided, the former relating to broad subjects of national importance, and the latter to minor matters and to some of the details of larger ones. For instance, currency, the national debt, banking, customs, taxation, and the subsidizing of industries pertain to "Political Economy," while economy of materials in designing and of cost of labor in construction, supplanting of hand-power by machinery, systemization of work of all kinds, adjustment of grades and curvature of railroads to traffic, and time- and labor-saving devices come under the head of "Economics."

The distinctions between the pure and the applied sciences are at times extremely difficult to draw, for one science often merges almost imperceptibly into one or more of the others.

The groups of pure sciences that have been enumerated may be termed:

The Mathematical Sciences,
The Physical Sciences,
The Physiological Sciences, and
The Social Sciences;

while the groups of applied sciences may be called:

The Organic Sciences,
The Constructive Sciences, and
The Economic Sciences.

In what follows the preceding nomenclature will be adopted.

The terming of engineering the "Constructive Science" is a happy conception, for engineering is truly and almost exclusively the science of construction. The functions of the engineer in all cases either are directly constructive or tend toward construction.

The engineer has ever had a due appreciation of all the sciences, imagination to see practical possibilities for the results of their findings, and the common-sense power of applying them to his own use.

Pure science (barring perhaps political economy) is not concerned with financial matters, and its devotees often look down with lofty disdain upon everything of a utilitarian nature, but engineering is certainly the science most directly concerned with the expenditure of money. The engineer is the practical man of the family of scientists. While he is sufficiently well informed to be able to go up into the clouds occasionally with his brethren, he is always judicious and comes to earth again. In all his thoughts, words, and acts he is primarily utilitarian. It is true that he bows down to the goddess of mathematics, but he always worships from afar. It is not to be denied that mathematics is the mainstay of engineering; nevertheless the true engineer pursues the subject only so far as it is of practical value, while the mathematician seeks new laws and further development of the science in the abstract. The engineer does not trouble himself to consider space of four dimensions, because there are too many things for him to do in the three-dimension space in which he lives. Non-Euclidian geometry is barred from his mind for a fuller understanding of the geometry which is of use to ordinary mankind. The mathematician demonstrates that the triangle is the sole polygonal figure which cannot be distorted, while the engineer, recognizing the correctness of the principle, adopts it as the fundamental, elementary form for his trusses. The mathematician endeavors to stretch his imagination so as to grasp the infinite, but the engineer limits his field of action to finite, tangible matters.

The geologist, purely studious, points out what he has deduced about the construction of the earth; but the engineer makes the mine pay.

The chemist discovers certain facts about the effects of different elements in alloys; but the engineer works out and specifies a new material for his structures. Again, the chemist learns something about the action of clay combined with carbonate of lime when water is added, and from this discovery the engineer determines a way to produce hydraulic cement.

The physicist evolves the theory of the expansive power of steam, and the engineer uses this knowledge in the development of the steam engine. Again, the physicist determines by both theory and experiment the laws governing the pressures exerted by liquids, and the engineer applies these laws to the construction of dams and ships.

The botanist with his microscope studies the form and construction of woods, while the engineer by experimentation devises means to preserve his timber.

The biologist points to bare facts that he has discovered, but the engineer grasps them and utilizes them for the purification of water-supplies.

In short, the aim of pure science is discovery, but the purpose of engineering is usefulness.

The delvers in the mysterious laboratories, the mathematical gymnasts, the scholars poring over musty tomes of knowledge, are not understood by the work-a-day world, nor do they understand it. But between stands the engineer with keen and sympathetic appreciation of the value of the work of the one and a ready understanding of the needs and requirements of the other; and by his power of adaptability he grasps the problems presented, takes from the investigators their abstract results, and transforms them into practical usefulness for the world.

The work of the engineer usually does not permit him to make very extensive researches or important scientific discoveries; nor is it often essential to-day for him to do so, as there are numerous investigators in all lines whose object is to deduce abstract scientific facts; nevertheless there comes a time occasionally in the career of every successful engineer when it is necessary for him to make investigations more or less abstract, although ultimately utilitarian; consequently it behooves engineers to keep in touch with the methods of scientific investigation, in order that they may either perform desired experiments themselves, or instruct trained investigators how to perform them.

The engineer must be more or less a genius who invents and devises ways and means of applying all available resources to the uses of mankind. His motto is "utility," and his every thought and act must be to employ to the best advantage the materials and conditions at hand. To be able to accomplish this object he must be thoroughly familiar with all useful materials and their physical properties as determined by the investigations of the pure scientists.

Many well-known principles of science have lain unused for ages awaiting the practical application for which they were just suited. The power of steam was known long before the practical mind of Watt utilized it in the steam engine.

The engineer is probably an evolution of the artisan rather than of the early scientist. His work is becoming more scientific because of his relations and associations with the scientific world. These relations of the engineer to the sciences are of comparatively recent origin, and this fact accounts for the rapid development in the engineering and industrial world of the past half-century. The results of this association have been advantageous to both the engineer and the pure scientist. The demands of the engineers for new discoveries have acted as an incentive for greater effort on the part of the investigators. In many instances the engineer is years in advance of the pure scientist in these demands; but, on the other hand, there are, no doubt, many valuable scientific facts now available which will yet work wonders when the engineer perceives their practical utility.

The engineer develops much more fully the faculty of discernment than does the abstract scientist, he is less visionary and more practical, less exacting and more commercial.

It is essential to progress that large stores of scientific knowledge in the abstract be accumulated and recorded in advance by the pure scientists, so that as the engineer encounters the necessity for their use he can employ them to the best advantage. The engineer must be familiar with these stores of useful knowledge in order to know what is available. This forms the scientific side of the engineer's work. While he must know what has been done by investigators, it is not absolutely necessary that he know how to make all such researches for himself; although, as before stated, there are times in an engineer's practice when such knowledge will not come amiss.

As engineers are specializing more and more, each particular specialty becomes more closely allied with the sciences that most affect it; consequently, to insure the very best and most economic results in his work the engineer must keep in close touch with all of the scientific discoveries in his line.

The early engineers, owing to lack of scientific knowledge, took much greater chances in their constructions than is necessary for up-to-date, modern engineers. There is now no occasion for an engineer to make any hazardous experiments in his structures, because by careful study of scientific records he can render his results certain.

In future the relations between engineers and the pure scientists will be even closer than they are to-day, for as the problems confronted by the engineer become more complex and comprehensive the necessity for accurate knowledge will increase.

The technical training now given engineers involves a great deal of the purely scientific; and it is evident that this training should be so complete as to give them a comprehensive knowledge of all the leading sciences that affiliate with engineering. There is no other profession that requires such a thorough knowledge of nature and her laws.

Of all the various divisions and subdivisions of the sciences hereinbefore enumerated and of those tabulated in the Organizing Committee's "Programme," the following only are associated at all closely with civil engineering:

Mathematics.
Geology.
Petrology.
Chemistry.
Physics.
Mineralogy.
Geography.
Astronomy.
Biology.
Botany.
Political Economy.
Jurisprudence.
Education.
Economics.

Attention is called to the fact that this list contains a number of divisions from the four main groups of pure sciences, viz., the mathematical, physical, physiological, and social, and but one division (economics) from the three groups of applied sciences, viz., the organic, constructive, and economic. The reasons why so little attention is to be given to the relation between civil engineering and the applied sciences are, first, in respect to organic science, there is scarcely any relation worth mentioning between this science and civil engineering, and, second, because the interrelations between civil engineering and other divisions of constructive science have already been treated in this address.

Of all the pure sciences there is none so intimately connected with civil engineering as mathematics. It is not, as most laymen suppose, the whole essence of engineering, but it is the engineer's principal tool. Because technical students are drilled so thoroughly in mathematics and because so much stress is laid upon the study of calculus, it is commonly thought that the higher mathematics are employed constantly in an engineer's practice; but as a matter of fact, the only branches of mathematics that a constructing engineer employs regularly are arithmetic, geometry, algebra, and trigonometry. In some lines of work logarithms are used often, and occasionally in establishing a formula the calculus is employed; but the engineer in active practice soon pretty nearly forgets what analytical geometry and calculus mean. As for applied mechanics, which, as the term is generally understood, is a branch of mathematics (although it involves also physics and other sciences), the engineer once in a while has to take down his old text-books to look up some principle that he has encountered in his reading but has forgotten. Strictly speaking, though, engineers in their daily tasks utilize applied mechanics, almost without recognition; for stresses, moments, energy, moments of inertia, impact, momentum, radii of gyration, etc., are all conceptions of applied mechanics; and these are terms that the engineer employs constantly.

There are some branches of the higher mathematics of which as yet engineers have made no practical use, and prominent among these is quaternions. When it first appeared the conciseness of its reasoning and its numerous short-cuts to results gave promise of practical usefulness to engineers, but thus far the promise has not been fulfilled.

Notwithstanding the fact that the higher mathematics are of so little use to the practicing engineer, this is no reason why their study should be omitted from or even slighted in the technical schools; because when an engineer has need in his work for the higher mathematics he needs them badly; besides, the mental training that their study involves is almost a necessity for an engineer's professional success.

Geology (with its allied branch, or more strictly speaking subdivision, petrology) and civil engineering are closely allied. Civil engineers are by no means so well versed in this important science as they should be. This, perhaps, is due to the fact that the instruction given on geology in technical schools is mainly from books, hence most graduates find difficulty in naming properly the ordinary stones that they encounter, and are unable to prognosticate with reasonable assurance concerning what a proposed cutting contains.

Geology is important to the civil engineer in tunneling, railroading, foundations, mining, water-supply, and many other lines of work; consequently, he needs to receive at his technical school a thorough course in the subject given both by text-books and by field instruction.

A knowledge of petrology will enable the engineer to determine readily whether building-stone contains iron which will injure its appearance on exposure, or feldspar which will disintegrate rapidly under the action of the weather or of acids from manufacturing establishments.

Next to mathematics, physics is undoubtedly the science most essential to civil engineering. The physicist discovers and formulates the laws of nature, the engineer employs them in "directing the sources of power in nature for the use and convenience of man." The forces of gravitation, adhesion, and cohesion; the pressure, compressibility, and expansibility of fluids and gases; the laws of motion, curvilinear, rectilinear, accelerated, and retarded; momentum; work; energy; the transformation of energy; thermodynamics; electricity; the laws of wave-motion; the reflection, refraction, and transmission of light; and the mass of other data furnished by the physicist form a large portion of the first principles of civil engineering.

The function of applied mechanics is to establish the fundamental laws of physics in terms suitable for service, and to demonstrate their applicability to engineering construction.

Chemistry is a science that enters into closer relations with civil engineering than does any other science except mathematics and physics, and as the manufacture of the materials of engineering approaches perfection the importance of chemistry to engineers increases. Within a comparatively short period the chemist has made it possible by analyzing and selecting the constitutents to control the quality of cast-iron, cast-steel, rolled-steel, bronze, brass, nickel-steel, and other alloys. The engineer requires certain physical characteristics in his materials, and obtains them by limiting the chemical constituents in accord with data previously furnished by the chemist. The proper manufacture of cement requires the combined skill and knowledge of the chemist and the mechanical engineer.

In water-supply the chemist is called in to determine the character and amounts of the impurities in the water furnished or contemplated for use. The recent discovery that the introduction of about one part of sulphate of copper in a million parts of water will effectively dispose of the algæ, which have long given trouble, is a notable instance of the increasing interdependence of these two branches of science, as is also the fact that the addition to water of a small amount of alum will precipitate the earthy matter held in suspension without leaving in it any appreciable trace of the reagent.

In the purification of water and sewage, in the selection of materials which will resist the action of acids and the elements, and in the manufacture of alloys to meet various requirements, a thorough knowledge of chemistry is essential.

A knowledge of mineralogy is requisite for a clear understanding of the nature of many materials of construction, but is otherwise of only general interest to civil engineers.

Geography in its broad sense is related to civil engineering in some of its lines, for instance, geodesy and surveying, but generally speaking there is not much connection between these two branches of science.

Astronomy is perhaps more nearly related to civil engineering than is geography, although it is so related in exactly the same lines, for the railroad engineer on a long survey must occasionally check the correctness of his alignment by observations of Polaris, and the coast surveyor locates point sby observations of the heavenly bodies.

Biology is allied to civil engineering mainly through bacteriology as applied to potable water, the treatment of sewage to prevent contamination of streams, and the sanitation of the camps of surveying and construction parties. The treatment of sewage has been given much more thorough study abroad than in this country, but the importance of its bearing upon life in the large cities of America is becoming better understood; consequently the progressive sanitary engineer should possess a thorough knowledge of bacteriology. In important cases, such as an epidemic of typhoid fever, the specialist in bacteriology would undoubtedly be called in; but a large portion of the work of preventing or eradicating bacterial diseases will fall to the lot of the sanitary engineer.

Botany comes in touch with civil engineering mainly, if not solely, in the study of the various woods used in construction, although it is a fact that a very intimate knowledge of this pure science might enable a railroad engineer or surveyor to determine approximately the characters of soils from plants and trees growing upon them. A knowledge of botany is of no great value to the civil engineer, and much time is often wasted on its study in technical schools.

Political economy is a science that at first thought one would be likely to say is not at all allied to civil engineering; but if he did so, he would be mistaken, because political economy certainly includes the science of business and finance, and civil engineering is most assuredly a business as well as a profession; besides, the leading engineers usually are either financiers themselves or advisers to financiers. Great enterprises are often evolved, studied, financed, and executed by engineers. How important it is then that they understand the principles of political economy, especially in its relation to engineering enterprises. It is only of late years that technical students have received much instruction in this branch of social science, and the ordinary technical school curriculum to-day certainly leaves much to be desired in respect to instruction in political economy.

Jurisprudence and civil engineering are closely allied, in that engineers of all lines must understand the laws of business and the restrictions that are likely to be placed upon their constructions by municipal, county, state, and federal laws. While most engineering schools carry in their lists of studies the "Laws of Business," very few of them devote anything like sufficient attention to this important branch of science.

Are the sciences of civil engineering and education in any way allied? Ay, that they are! and far more than most people think, for there is no profession that requires as much education as does civil engineering. Not only must the would-be engineer study the various pure and applied sciences and learn a great mass of technical facts; but he must also have in advance of all this instruction a broad, general education — the broader the better, provided that no time be wasted on useless studies, such as the dead languages.

The science of education is so important a subject for civil engineers that all members of the profession in North America, more especially those of high rank, ought to take the deepest interest in the development of engineering education, primarily by joining the special society organized for its promotion, and afterwards by devoting some of their working time to aid this society in accomplishing its most praiseworthy objects.

The science of economics and that of civil engineering are, or ought to be, in the closest possible touch; for true economy in design and construction is one of the most important features of modern engineering. Every high-class engineer must be a true economist in all the professional work that he does, for unless one be such, it is impossible to-day for him to rise above mediocrity.

True economy in engineering consists in always designing and building structures, machines, and other constructions so that, while they will perform satisfactorily in every way all the functions for which they are required, the sum of their first cost and the equivalent capitalized cost for their maintenance, operation, and repairs shall be a minimum. The ordinary notion that the structure or machine which is least in first cost must be the most economical is a fallacy. In fact, in many cases, just the opposite is true, the structure or machine involving the largest first cost being often the cheapest.

Economics as a science should be taught thoroughly to the student in the technical school, then economy in all his early work should be drilled into him by his superiors during his novitiate in the profession, so that when he reaches the stage where he designs and builds independently, his constructions will invariably be models of true economy.

It has been stated that the relations between civil engineering and many of the pure sciences are very intimate, that the various branches of engineering, although becoming constantly more and more specialized, are so interdependent and so closely connected that they cannot be separated in important constructions, that the more data the pure scientists furnish the engineers the better it is for both parties, and that a broad, general knowledge of many of the sciences, both pure and applied, is essential to great success in the engineering profession.

Such being the case, the question arises as to what can be done to foster a still closer affiliation between engineering and the other sciences, and how engineers of all branches and the pure scientists can best be brought into more intimate relations, in order to advance the development of the pure sciences, and thus benefit the entire world by increasing the knowledge and efficiency of its engineers.

One of the most effective means is to encourage the creation of such congresses as the one that is now being held, and to organize them and arrange their various meetings so as to secure the greatest possible beneficial results.

Another is for such societies as the American Association for the Advancement of Science and the Society for the Promotion of Engineering Education to take into their membership engineers of good standing, and induce them to share the labors and responsibilities of the other members.

Conversely, the various technical societies should associate with them by admission to some dignified grade (other, perhaps, than that of full member) pure scientists of high rank and specialists in other branches of constructive science, and should do their best to interest such gentlemen in the societies' objects and development.

A self-evident and most effective method of accomplishing the desired result is to improve the courses of study in the technical schools in every possible way; for instance, by bringing prominent scientists and engineers to lecture to the students and to tell them just how scientific and professional work of importance is being done throughout the world, by stimulating their ambition to rise in their chosen professions, by teaching them to love their work instead of looking upon it as a necessary evil, and by offering prizes and distinctions for the evidence of superior and effective mental effort on the part of both students and practicing engineers.

There has lately been advanced an idea which, if followed out, would aid the development of engineering more effectually than any other possible method, and incidentally it would bring into close contact scientists in all branches related directly or indirectly to engineering. It is the establishment of a great post-graduate school of engineering in which should be taught in every branch of the profession the most advanced subjects of all existing knowledge that is of real, practical value, the instructors being chosen mainly from the leading engineers in each specialty, regardless of the cost of their services. Such specialists would, of course, be expected to give to this teaching only a few weeks per annum, and a corps of regular professors and instructors, who would devote their entire time and energies to the interests of the school, would be required. These professors and instructors should be the best that the country possesses, and the inducements of salary and facilities for investigation that are provided should be such that no technical instructor could afford to refuse an offer of a professorship in this school.

Every modern apparatus needed for either instruction or original investigation should be furnished; and arrangements should be made for providing means to carry out all important technical investigations.

It should be the duty of the regular faculty to make a special study of engineering literature for the benefit of the profession; to prepare annual indices thereof; to put into book form the gist of all technical writings in the *Transactions* of the various engineering societies and in the technical press that are worthy of being preserved and recorded in this way, so that students and engineers shall be able to search in books for all the data they need instead of in the back files of periodicals; to translate or assist in the translation of all engineering books in foreign languages, which, in the opinion of competent experts, would prove useful to engineers or to the students of the school; and to edit and publish a periodical for the recording of the results of all investigations of value made under the auspices of the institution.

In respect to what might be accomplished by such a post-graduate school of engineering the following quotation is made from the pamphlet containing the address in which the project was advanced:[1]

"The advantages to be gained by attendance at such a post-graduate school as the one advocated are almost beyond expression. A degree from such a school would always insure rapid success for its recipient. Possibly for two or three years after taking it a young engineer would have less earning capacity than his classmates of equal ability from the lower technical school, who had gone directly into actual practice. However, in five years he certainly would have surpassed them, and in less than ten years he would be a recognized authority, while the majority of the others would be forming the rank and file of the profession, with none of them approaching at all closely in reputation the more highly educated engineer.

"But if the advantages of the proposed school to the individual are so great, how much greater would be its advantages to the engineering profession and to the entire nation. After a few years of its existence there would be scattered throughout the country a number of engineers more highly trained in the arts and sciences than any technical men who have ever lived; and it certainly would not take long to make apparent the impress of their individuality and knowledge upon the development of civil engineering in all its branches, with a resulting betterment to all kinds of constructions and the evolution of many new and important types.

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[1] Higher Education for Civil Engineers: an Address to the Engineering Society of the University of Nebraska, April 8, 1904, by J. A. L. Waddell, D.Sc., LL.D.

"When one considers that the true progress of the entire civilized world is due almost entirely to the work of its engineers, the importance of providing the engineering profession with the highest possible education in both theoretical and practical lines cannot be exaggerated.

"What greater or more worthy use for his accumulated wealth could an American multi-millionaire conceive than the endowment and establishment of a post-graduate school of civil engineering."

Another extremely practical and effective means for affiliating civil engineering and the other sciences is for engineers and professors of both pure science and technics to establish the custom of associating themselves for the purpose of solving problems that occur in the engineers' practice. Funds should be made available by millionaires and the richer institutions of learning for the prosecution of such investigations.

Another possible (but in the past not always a successful) method is the appointment by technical societies of special committees to investigate important questions. The main trouble experienced by such committees has been the lack of funds for carrying out the necessary investigations, and the fact that in nearly every case the members of the committees were unpaid except by the possible honor and glory resulting from a satisfactory conclusion of their work.

Finally, an ideal but still practicable means is the evolution of a high standard of professional ethics, applicable to all branches of engineering, and governing the relations of engineers to each other, to their fellow workers in the allied sciences, and to mankind in general.

As an example of what may be accomplished by an alliance of engineering and the pure sciences, the construction of the proposed Panama Canal might be mentioned. Some years ago the French attempted to build this waterway and failed, largely on account of the deadly fevers which attacked the workmen. It is said that at times the annual death-rate on the work ran as high as six hundred per thousand. Since the efforts of the French on the project practically ceased, the sciences of medicine and biology have discovered how to combat with good chances for success the fatal malarial and yellow fevers, as was instanced by the success of the Americans in dealing with these scourges in the city of Havana after the conclusion of the Spanish-American war.

The success of the American engineers in consummating the great enterprise of excavating a navigable channel between the Atlantic and Pacific oceans (and concerning their ultimate success there is almost no reasonable doubt) will depend largely upon the assistance they receive from medical science and its allied sciences, such as hygiene, bacteriology, and chemistry.

Geological science will also play an important part in the design and building of many portions of this great work, for a comprehensive and correct knowledge of the geology of the Isthmus will prevent the making of many costly mistakes, similar to those that resulted from the last attempt to connect the two oceans.

Again, the handling of this vast enterprise will involve from start to finish and to an eminent degree the science of economics. That this science will be utilized to the utmost throughout the entire work is assured by the character and professional reputation of both the Chief Engineer and the members of the Commission.

Notwithstanding, though, the great precautions and high hopes for a speedy and fortunate conclusion of the enterprise with which all concerned are starting out, many unanticipated difficulties are very certain to be encountered, and many valuable lives are likely to be expended on the Isthmus before the first steamer passes through the completed canal. Engineering work in tropical countries always costs much more and takes much longer to accomplish than is at first anticipated; and disease, in spite of all precautions, is very certain to demand and receive its toll from those who rashly and fearlessly face it on construction works in the *tierra caliente.* But with American engineers in charge, and with the finances of the American Government behind the project, success is practically assured in advance.

What the future of civil engineering is to be, who can say? If it continues to advance as of late by almost geometrical progression, the mind of man can hardly conceive what it will become in fifty years more. Every valuable scientific discovery is certainly going to be grasped quickly by the engineers and put to practical use by them for the benefit of mankind, and it is only by their close association with the pure scientists that the greatest possible development of the world can be attained.

THE PRESENT PROBLEMS OF TECHNOLOGY

BY LEWIS MUHLENBERG HAUPT

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STANDING in the shadow of the century which this greatest of expositions signalizes, it is fitting that one should consider its fruition, as typified in these exhibits, and also indulge in a forecast of the magnificent possibilities which they portend.

Amongst the varied subjects assigned for the consideration of this distinguished international Congress, that of "Present Problems" would seem, from its title, to be restricted to the existing status of civil engineering; yet it is so intimately related to both history and prophecy as to involve a brief reference to its past evolution and its future potentialities.

This is the more evident when it is considered that the present is but an infinitesimal link between the two infinities, past and future; the former, being the storehouse of models, tools, and experiences; the latter, the great laboratory of psychological possibilities, rendered attainable only through the application of present activities.

Whenever the curve of progress[1] in any art or science may be traced from sufficiently exact data, its present status becomes at once known and its prospective possibilities may be predicted within reasonable limits of certainty, under similar conditions.

It is by such graphical records of quantitative events that the composite results of history are most clearly projected forward into the domain of accurate predictions. The grandest problem of the present is to portray definitely that curve of progress which will point the way most surely for succeeding generations.

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[1] See *Scientific Research*, by Dr. R. H. Thurston, *Science*, vol. XVI, 1902.

To this end it is important that all of the elements which determine its *locus* should be duly weighed and coördinated, since the resultant law and prediction must depend upon the accuracy of, and the interpretation placed upon, the available data used in the compilation.

Some of the physical elements are reasonably well understood with reference to the laws governing their action, such as universal and terrestrial gravitation; the relations of thermic and dynamic, chemical and electric energies; the conservation of force, or the mutations of matter and the like; but who can fathom the basic principles underlying all physical activities and trace the origin of all energies as revealed in the life of organic bodies?

In the language of our lamented and distinguished physicist, Dr. R. H. Thurston:

"All life and movement, whether of man, animal, vegetable, seasons, suns and planets, arts, commerce, civilization, intellectual, moral or physical worlds, depend upon transformations of preëxisting energy. . . . We have learned to compute the velocity, refraction and reflection of light, but we still know little of its exact character as motion of molecules.

"We know the related form, heat-energy, in its sensible effects; but we are still unable to differentiate the one from the other. . . We can produce and utilize electricity in many ways, but we do not even know what it is or how its transformations from other energies are effected. We work with these three forms of power, but we do not know what is the nature of the substance through which they act to produce their beautiful, marvelous, world-impelling effects." He adds in substance:

The chemist, by analysis, can determine the composition of compounds, but he has only recently discovered that his theoretical basic atom can be atomized. The physicist finds in the spectroscopic lines a strange language of which he lacks the key. He can isolate the phosphorus of steel, but cannot produce that of the glow-worm or the firefly. The analyst can separate organic matter into its elements, but he cannot by synthesis reconstruct the storage batteries of brain and spine nor the subtle alchemy of the bee, which converts the nectar of the rose into its sublimated honey, nor the vegetable verdure of the field into the life-giving, lacteal pabulum of the mammal for the sustenance of its offspring.

The astronomer has unraveled the laws of the motions of the celestial bodies, but he is unable to determine their duration, origin, or destiny. His little span of life is all too brief to enable him to reveal the secrets of their Maker.

The geologist probes the bowels of the earth, from its loftiest to its lowliest depths, but fails to ascertain its age or longevity or to state whether it shall endure for a million years or perish in a season.

The biologist has yet to learn the mysteries of life in plant and animal and has not even unraveled the secret of sex in generation. He studies the mechanism of the fish, but cannot explain the process of separating the oxygen from the medium in which it moves; so likewise he may understand the structure and mechanism of the bird, but fails to learn the mysterious power whereby it soars aloft, and, perceiving its prey from afar, captures it.

The anatomist may know to an ounce the power developed in an animal per pound of muscle, but he cannot say how that power is originated, transferred, or exerted by the transmitting thread of the working muscles. Our authority concludes:

"The engineer has learned how to convert the potential energy of perhaps a myriad ages into steam and to apply it to the dynamics of the factory or locomotive, but in doing so he wastes from four fifths to nine tenths of it. He transforms the elastic force into an electric current, but frequently loses as much as he applies at the tool's edge. He diverts the energy of the waterfall into an electric-light current with its concomitant heat-rays, while the glow-worm shames the man, producing light without heat and heat without light.

"He crowds his fellow man into mills and factories, but he has not yet solved the social problem of giving to each an individual life, work, and wage, with comfort, health, and happiness in just proportion."

Thus the man of science finds that the acquisition of learning, gain in knowledge, and increasing appreciation of the wonders of creation, only serve to impress upon him the greatest responsibilities, possibilities and opportunities as well as the mightier mysteries of its Maker, stimulating him to nobler aspirations, more earnest labor and higher aims and giving him a larger faith and a stronger sense of the infinitude of duty and opportunity.

In short, no more sublime arraignment of the impotency of man to solve the ever present problems of his existence and necessities, in the most economic manner, can be found than that recorded in the closing chapters of the Book of Job, wherein the Lord charges him with "darkening counsel by words without knowledge" and proceeds to catechize him as to the origin of the world and its phenomena, in a manner so profoundly majestic that most of the queries remain unanswered even unto this day.

These same interrogatories therefore constitute a catalogue of present problems in all departments of science, and their solution can best be approached only by a closer communion with the omniscient Source of all Wisdom.

Most of the great inventions and discoveries which have ennobled and advanced civilization have come from inspiration and deep research, prompted by the exigencies of time and place, yet but few efforts have been wholly successful, for, as the poets have said:

> " God hath appointed wisdom the reward of study!
> 'T is a well of living waters,
> Whose inexhaustible bounties all might drink,
> But few dig deep enough."

Yet let no one fear that the field of research in any of the mental or physical sciences will ever become exhausted, for the Source is infinite.

If all the wisdom of all the sages of mankind, in all ages from the foundation of the world, were summed into a series and integrated between the limits of zero and infinity, they could not compass the unfathomable resources of the Almighty. "Can man by searching find out God?"

To solve the problems confronting the present generation, it is fundamental that the laws and properties governing mind and matter be more fully understood and better applied.

Much energy is wasted and many failures follow from the crude and inexperienced methods adopted, which too often violate the laws of nature and leave but a wreck to tell the story; for "few dig deep enough."

Some of these laws are so occult that man has not yet wholly unraveled their mysteries. Has not the wisest of kings admitted: "There be three things which are too wonderful for me, yea, four which I know not: The way of an eagle in the air; the way of a serpent upon a rock; the way of a ship in the midst of the sea; and the way of a man with a maid."

And do not these four things involve all the elements of the technological problem embodied in the transportation question of today? aëronautics, dynamics, navigation, and psychology, — transportation in the three media of air, water, and land, as well as such mental conceptions of their conditions and requirements as shall render them all equally available; which state man has not yet attained unto. There is therefore a large sphere still open in this field for future research.

It will be the main purpose of the writer, therefore, to outline the elements which must be focused upon this particular phase of economic transportation, having in view the attainment of the best results.

This attainment is conditioned upon something more than the fundamental conception of the ideal or its mere graphical expression in the formal technology of the shop or the patent office. Its practical fulfillment necessitates a large accumulation of means, men, and materials, and their intelligent coördination in certain prearranged sequences, at definite times and under favorable environments. Moreover, it is essential that all of these factors should work together harmoniously under a single controlling head, impelled by an earnest, zealous, generous, and humane desire to secure the best effects. But it, unfortunately, too frequently happens that vested interests, jealousy, ignorance, cupidity, conservatism, strikes, and physical obstacles conspire to delay or defeat the best-laid plans.

It becomes the part of wisdom, therefore, to consider both sides of the equation before embarking on any extensive innovation, in the nature of works affecting large interests, however beneficially.

The successive stages which mark the progress of great enterprises may be conveniently formulated into a *General Law of their Development*, of which the first step is *educational.*

It is opposed by

(1) *Ignorance,* on the part of the public as to its possibilities;

(2) *Indifference,* as to its economics, after they have been stated;

(3) *Incredulity* as to its feasibility, or utility before demonstration.

The second step enters the forensic arena where efforts to secure authority from legislative bodies are met by

(4) *Argument* which, failing to convince, leads to

(5) *Bribery,* instigated by vested rights or cupidity, and

(6) *Patronage,* withdrawn as a punishment to the offenders, or granted as a reward for opposition. But should the project outlive these allied enemies and enter the third phase of active construction, the opponents then have recourse to

(7) *Violence,* by use of physical obstacles or force to obstruct the works;

(8) *Persecution,* leading to an impugnment of the motives, character, and credit of the parties at interest;

(9) *Murder,* either by premature death from excessive futile, unrequited efforts or by actual assassination or war, to remove the guiding spirits of great movements and thus debar their consummation.

These psychological phases being outlived and the physical forces being overcome, the way to success is at length assured. The former elements are not so often taken into the account as the latter, yet they are frequently the most subtle, uncompromising, and intangible. Underneath many of the great achievements of the world, in the arts of peace, there lies buried a romance of heroic endurance, self-abnegation, and masterful resource, intensely realistic, which would put the pages of fiction to shame, were they made public. Truly, "Peace hath her victories no less renowned than war."

Whilst the above reflections may appear to be merely "glittering generalities" they are in fact fundamental requirements in the successful execution of great projects, since, however thoroughly an inventor may have convinced himself of the great practical economy of his theory, he cannot point to his demonstration as a basis for public confidence and the underwriting of his conceptions, until he has established his precedent; and, on the other hand, it is impracticable to establish his claims by actual works, until he has secured his capital and authority. Especially is this true of great improvements involving governmental jurisdiction, where the personnel and responsibility for appropriations are constantly shifting, and trained experts are not permanently available in the conduct of the works. Although this is a problem of government, it is intimately related to the questions at issue, viz., the work of the civil engineer in providing the way for the safe, rapid, and economical distribution of the products of the earth for the benefit of mankind. Works of this class, requiring the opening of lines of least resistance between distant centres, are impracticable without the exercise of the rights of eminent domain, accompanied by the accumulation of large amounts of capital and the control of labor whereby the physical resistances to traffic may be reduced to a minimum.

Of the three elements, earth, water, and air, the first offers the greatest resistance because of its density and the irregularity of its surface. It has therefore been the crucial problem of all ages so to modify it that "every valley shall be exalted and every mountain and hill shall be made low, and the crooked shall be made straight and the rough places plain," that a highway might be there, over which the peaceful revolutions of the wheels of commerce might cement the nations of the earth and distribute its products. But whilst history testifies to the excellence in alignment, grades, and durability of some of the ancient roads, it fails to record any evidences of such magnificent avenues of trade as have been developed within the space of a single life in the railways constructed during the past century.

These were unknown and impossible prior to 1825, since the state of the mechanic arts did not furnish materials in sufficient quantity and quality to permit of such constructions. The demand, however, created the supply, the storehouses of the earth yielded an abundance of the raw materials, the railways and waterways assembled them at convenient centres of industry, the metallurgist and chemist refined and reduced them to improve their quality and durability; the mechanical and electrical engineers developed new machinery for increasing the output at reduced cost, and thus supplied the markets with structural materials for roads, bridges, and buildings far beyond any possible conception of even fifty years ago. Then, steel rails were unknown and the durability of the wrought-iron rails, which had supplanted those of cast-iron, was limited in some instances to a few months only, but at this critical period the invention of the Bessemer pneumatic process, followed by Gilchrist, Siemens-Marten, and others, supplied an urgent necessity as to quality; the various inventions of George and John Fritz, Alexander Holley, William R. Jones, Nasmyth, Nobel, Krupp, and many others met the demands for quantity, while the development of commercial channels and establishment of improved plants at strategic points has reduced the cost and increased the output to such an extent that there is no retardation as yet visible in the curve of progress so far as the quantity is concerned. The last fiscal year (1902) shows an increment of 9626 miles of railroad in the country which exceeds that of any year since 1890, so that the demand for construction material continues to be one of the problems of the present.

Especially is this the case with wooden cross-ties having a life of only from seven to ten years. They require frequent renewals at the expense of our hard-wood forests, with incidental injury to the entire country from denudation, causing rapid erosion of uplands, floods, and barren wastes. Therefore the recently established policy of irrigation and reforestation has come none too soon to check the evils of the wholesale slaughter of our forests.

The increasing paucity of timber and the greater strength, durability, and economy of the metals have led to their rapid substitution for the vegetable fibers, in most of the engineering structures, but the tendency is now returning strongly to the use of stone, brick, or concrete wherever they are practicable and available, as the best material for bridges and buildings. Where they cannot be secured, artificial concretes and cements are frequently used either singly or in combination with the metals in the form of meshings for imparting tenacity. Although much progress has been made in this class of material, it yet remains to discover the secret of the ancient compounds as instanced in the remarkably durable water-tanks of the Arabs, built at Aden about 600 years B. C., and still in a perfect state of preservation.

Notwithstanding the extended researches made upon the properties of material for structural purposes, much still remains to be discovered. One of the latest investigations made as to the use of pure sand, encased in light sheet-metal tubing, merely to prevent it from flowing, reveals some astonishing results in transmitting pressure in the form of beams subjected to cross-strains, or in the form of columns carrying heavy loads. These investigations, conducted by Prof. A. V. Sims, may result in important economic changes in engineering structures in the near future, when reduced to a practical basis. They cannot be elaborated in this paper.

But the selection and preparation of suitable materials for structures are details which rather belong to the domain of the chemist and physicist than to the engineer whose province it is to design, assemble, and direct work, whereby he may more generally apply the resources of nature to the wants of man.

Fuel

For this purpose, power is a fundamental factor, and for many years it was readily derived from the forests, so generously dispersed over the earth; but the rapid increase in the demand for all classes of motors as well as for domestic and structural purposes has threatened an early exhaustion of this supply. For locomotives, it soon became impracticable, while for the modern steamship it would be absolutely impossible. With the discovery of coal and its stored energy, the world was revolutionized. The first quarry for anthracite was opened at Summit Hill, Pennsylvania, in 1792, but the cost of hauling to the market was such as to prohibit its use. Thus was stimulated the construction of the Lehigh, Schuylkill, and Union canals and the Switchback Railroad early in the last century, the progenitors of our extensive system of public works, which has been developed by private capital and enterprise with occasional aid from local and general governments until the railroads of the country now exceed 215,000 miles, representing a capital of over 14,000,000,000 dollars and carrying over 1,200,000,000 tons of freight per annum, at an average cost of 7.6 mills per ton-mile.

The rapid increase in the demand for anthracite coal from the Schuylkill and Lehigh regions resulted in a maximum yield, for some years, of 65,000,000 tons per annum; but the discovery and working of large deposits of soft coal in West Virginia and many other localities, as well as the greater cost of mining, has reduced the output of hard coal to about 59,000,000 tons, with resulting increase of price, while the bituminous mines are now furnishing 260,000,000 tons. This, with the opening of the free-working iron ores of Lake Superior and the exceptionally cheap transportation on the Great Lakes, has concentrated the mammoth iron and steel plants near their borders and given to the world a new stimulus in structural materials. Coke, natural gas, and petroleum have also aided in the general movement for cheaper power, and the generation of artificial gas, as the most effective form of energy, has proceeded, *pari passu*, with the demand for greater economies. Attention is now being concentrated upon the utilization of the dynamic agencies of the earth, found in her water-courses, atmosphere, and electricity, to great advantage for the generation and transmission of power through long distances and under high tension, with corresponding gain in efficiency. Yet these fields are still in an embryotic state. The possibilities of the radio-active group is at present beyond the power of man to predict. The accomplishment of alleged impossibilities is becoming a commonplace event.

The great economy and convenience of fuel in a gaseous form would seem to be manifest from the mere statement of the relative calorific powers of wood, 6480° F.; coke, 13,550° F.; bituminous coal, 13,692°; anthracite, 14,200°; ordinary illuminating gas, 23,000°, and natural gas 35,000°, which makes it nearly six times greater than that of wood and threefold that of coal, yet a modern publication recently announced the superior "economy of coal as compared with oil and natural gas for fuel."

In 1881 the late Sir Frederick Bramwell predicted that by the year 1931 the steam engine would be of interest only as a relic and would be supplanted by gas motors. Subsequent facts sustain in some measure the prediction, for to-day they have reached units of 1750 h. p. and are extensively used in many industries.

The fear that the introduction of electric plants would exterminate gas for lighting and power has not been realized, since it is found more economical in many cases to make the gas-plant supplementary to the electric and thus increase the scope and efficiency of both. But the application of electricity as a motor, whether developed from water or steam, is merely a phase in the evolution of power, which will ultimately yield in large part to the superior advantages of pneumatic transmission from the natural sources now available in the great waterfalls of the world, when they are more fully appreciated and properly harnessed.

Although much attention has been devoted to the application of the tidal energy to manufacturing purposes, but little practical use has thus far been made of it. This enormous storehouse is yet awaiting the touch of a master hand to utilize it advantageously.

Aside from the source and character of the power which may ultimately be employed, there is also great room for further economies in the handling of the enormous tonnage already required to meet present demands. Here the problem has been and still is to increase the ratio of live to dead load and to reduce the resistances by betterments in alignment, grade, distance, and terminal facilities even at large increase of capital. Still the delays in handling and drilling trains, composed of relatively small units and containing miscellaneous freights, in complicated yards, and the use of cars for many days for storage, necessitates great expense for which no adequate solution has been provided, although some relief may be obtained by the earliest possible transfer to waterways at the nearest practicable point, thus substituting the short for the long haul, in some cases. In others, where bulky freight, like ore, coal, or grain is handled, great improvements have been introduced so that the entire contents of each car may be dumped through chutes into the hold of the vessel in one operation. The capacity of the car has also been increased so that instead of the paying load being less than the weight of its carrier, it is now about three times greater. Probably the greatest advance in economic transportation ever effected was that which has revolutionized the movement of petroleum from the oil-wells of Pennsylvania to tidewater. This product was formerly handled by the trunk-line railroads in specially constructed tank-cars, required to return empty, thus reducing the live load to about 25 per cent of the total for the round trip and costing forty cents per barrel for the freight. To control the market and limit the output a combination was effected amongst the common carriers, which made it impossible for independent producers to market their oil.

In this extremity, *carte blanche* was given to an experienced engineer,[1] in 1878, to secure a continuous right-of-way, in fee, across the states of Pennsylvania and Maryland and to construct a pipe-line to the seaboard, without the exercise of the right of eminent domain and in the face of a most determined and well-organized opposition. By tact, energy, and strategy, this was successfully accomplished in a remarkably short time, and by the use of the principle of the hydraulic gradient and the mutually automatic regulation of the pumping-plants, of which only four were required, the cost of this movement was reduced ninety per cent and the cordon was broken, to the great relief of both producer and consumer. After which demonstration, general pipe-line laws were adopted and other lines constructed so that the tank-car is now almost a relic of the past. Thus the oppression of a trust has operated to effect an economy which has reacted upon it for its own greater emoluments as well as for the public benefit.

The engorgement which has resulted in railroad centres from the concentration of freight at certain seasons may be partially relieved by so improving the feeders and outlets of all the avenues of transportation as to distribute the movement more uniformly over a longer period by the improvement of the *common roads* to make them available at all seasons, with the expenditure of less power and also of the internal *waterways* of the country, that they may be utilized to relieve the traffic by distributing raw materials which will not bear a long rail-haul. Moreover, the bars which obstruct all harbor inlets along alluvial coasts constitute a serious obstacle to the general distribution of commerce by requiring vessels to clear light, wait for favorable conditions of wind and tide, or store their freight for lack of sufficient draught. It is even now true that the most economical vessel cannot be built because of the existing limitations of channels and ports, not yet removed, and which, notwithstanding the great improvements in hydraulic dredging-plants, cannot be permanently relieved by these mechanical devices.

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[1] General Herman Haupt.

The great fertile plains and deltas at the mouths of sedimentary rivers are but the natural depositories for the detritus fed to them by their hydraulic conveyors whose source is in the highlands, which streams carry hundreds of millions of yards of earthy matter to the sea, where it must ultimately rest.

The problem here is, then, so to dispose of this deposit by natural agencies as to prevent its obstructing the channels of commerce. This can be accomplished by utilizing the potential energy of the stream itself by means of a concave resisting medium, placed across the bar in such position as to develop a reaction and scour, which changes the form of the channel and transports the sediment laterally to the counterscarp thus created, and from which the waves and littoral currents remove it.

This method has been demonstrated by actual experience and is found to effect great economies in cost of construction and maintenance, since the trace of the work is less than half as long as that required by the preëxisting methods, and there is no corresponding bar advance, but an automatic adjustment of the channel and dump to the requirements of that particular stream and locality.

This is a physical problem which has impressed itself with more and more emphasis, because of the rapid strides made in commerce and manufactures and the greatly increased demands for larger tonnage and correspondingly deeper channels. The mere cutting of a ditch across an ocean bar in the face of the ever active forces which created it is not a satisfactory nor an economic solution of this question. It is estimated that the automatic reaction breakwater would have saved over fifty millions of dollars in the past decade in this country alone, had it not been for the conservatism which was unable to concede its advantages prior to an actual demonstration, and which has debarred its general introduction.

This incident is cited, without detail of the resistances it has overcome, merely to illustrate the truths of the general principles enumerated, as to the elements opposed to progress, in the introduction to this paper.

Returning now to the general theme as to the future of economic transportation, it will be found necessary to devote large appropriations from the treasuries of states and nations to the betterment of the public highways, for the general welfare and as feeders to the extensive systems of railroads, that they may utilize their rolling-stock and power to best advantage. In this work the railway companies can well afford to expend large sums for road-metaling in coöperation with local interests, as some are now doing, instead of building railroads for their exclusive use and control, to be maintained at great cost. The highway, thus improved, will become available for all classes of vehicles (and at all seasons), from the freight-wagon to the automobile, and will play a most important part in the commercial, social, and industrial well-being of the country. The introduction of the trolley has also served to elevate the general condition of mankind by the facilities it has afforded for the circulation of mind and matter at a very reasonable cost; while the various devices for transmitting knowledge by electric agencies, with or without metallic conduits, has given a great impetus to the interchange of knowledge and the promotion of all classes of improvements. Yet each innovation has had to establish its *raison d'être* by a long contest and only the fittest have survived. The war of extermination waged by certain transportation monopolies against competition has in general established the principle that the greater the distribution and mobilization of the population, the greater the resulting benefits to the common carrier.

Thus the improvement of waterways has invariably increased the profits of the railways from the resulting greater tonnage even though carried at reduced rates; the building of trolleys, so long bitterly opposed, is now recognized as a public benefaction; the improvement of the highways, so strenuously resisted by the rural districts, is now hailed with delight as adding immensely to the value of the farm and at the same time reducing the cost of its products to the consumer.

This apparent paradox results from the saving in the waste formerly incurred in overcoming needless resistances, which has gone to increase the margin available for transportation for the benefit of producer, consumer, and carrier alike.

The Isthmian Canal question, the solution of which has been the desire of nations for four centuries, is still an ever-present problem. Though a route has been selected and the right-of-way secured, the canal is not *un fait accompli*. Were it so, the cost of transportation, by water, between the North Atlantic and North Pacific ports would be reduced to about one third of the existing rates, with far greater safety and with a corresponding increase in the potentiality of the fleets. Even under existing conditions, with the necessity of circumnavigating South America, the railroads cannot compete with the Cape Horn route for the reason that the average charge for the overland movement, at 7.6 mills per ton-mile, would make the cost of transportation about $21, which is more than the market value of the great bulk of the tonnage.

It is therefore a physical impossibility, at present rates, to carry this traffic by rail at a reasonable profit, whereas it could readily be moved by the water-route at a charge of less than $5 per ton, thus stimulating manufactures and building up a higher class of freight for local distribution with a shorter haul, for the general benefit not only of the railways but of all parties at interest. Under existing conditions the total overland tonnage of all the transcontinental lines probably does not exceed 2,000,000 tons per annum.

It is estimated that an Isthmian route would save to the commerce of the world not less than $200,000,000 annually, or an amount equal to our foreign freight bill, so that there can be no question as to its justification and imperative necessity at any cost.

Another pressing desideratum in the development of international commerce is the enlargement of the internal waterways of our own country, which have not kept pace with the traffic requirements.

The state of New York has at length awakened to the necessity of meeting the competition of her energetic neighbors and is about to respond generously to the demand for a larger waterway from the Great Lakes to tidewater, hoping by a limited twelve-foot draft to compete successfully with one of much greater capacity traversing a shorter route. The fallacy of this proposition would seem to be self-evident, but the general government makes no appropriation for this great enterprise.

The Chicago Sanitary District has by its own contributions accomplished the triple benefits of improving its water-supply, disposing of its sewage in a harmless manner, and creating an ample navigable channel across the "Sag" between Lake Michigan and the Illinois River (a model of which may be seen in the Liberal Arts Building).

It now remains to enlarge and improve the remainder of that route all the way to the Gulf of Mexico and to open the mouth of the great Mississippi River, to permit the rapid escape of the flood waters, and to improve its navigation; but the means to this end cannot be treated in the limits of this paper. Suffice it to say that it is still a present problem, as is admitted by the last report of the Mississippi River Commission in these words: "Experiments are continually being made looking to the best use of the available material and the development of appliances and methods which may be economically and effectively employed when Congress shall provide for such systematic improvement."

This quotation serves to emphasize one of the most serious obstacles to the development of the commercial interests of the country, namely, the meagre appropriations made only biennially by Congress for works of this class. Attention is also directed to the absence of all competition in the preparation of the designs and plans and to the rigid requirements of the specifications, which have the effect of deterring many responsible companies from underwriting government contracts, thus increasing the cost of these important improvements with no guaranty as to the results to be secured.

The effect of the absence of cheap water transportation from the interior to the seaboard is impressively exhibited by the fall in the average farm-price of the staple cereals as the distance from the seaboard increases. The export price being the standard, the cost of the overland haul must be deducted to determine the farm-value. It is found from the statistics of the Department of Agriculture, during the past decade, that if the average price of wheat on the Atlantic seaboard is 79 cents per bushel, it will be 78 cents for New York State; 72 for Pennsylvania; 69 for Ohio; 65½ for Indiana; 64 for Illinois; 60.8 for Missouri; 58 for Iowa; 53 for Kansas; 50.9 for Nebraska, which is the lowest area reached.

The ability to ship via Kansas City and St. Louis down the Mississippi River contributes to raise the value of farm-products in Kansas as compared with Nebraska to such an extent that Nebraska would have saved nearly $15,000,000 in one year could her crops have been sold at Kansas prices (in 1901).[1]

The same general principles prevail in other states, to raise the value of agricultural products and consequently of real estate, as the waterways are more accessible and capacious; yet the demands for their enlargement, improvement, and emancipation from tolls are far in excess of the ability of the Government to provide for them either financially or administratively. The total estimate for works required at the present time exceeds the entire cost for construction and maintenance of rivers and harbors, since the foundation of the Republic.

Yet private parties and localities are prohibited by law from relieving their own exigencies, by their own methods, at their own expense and risk, without charge upon commerce, thus compelling them to submit to the non-competitive tariffs, which restrain trade and drive it to other more favored locations, or to go into liquidation.

There would seem to be great necessity for further remedial legislation in line with the recent resolutions of the National Board of Trade, authorizing the letting of contracts for this class of work

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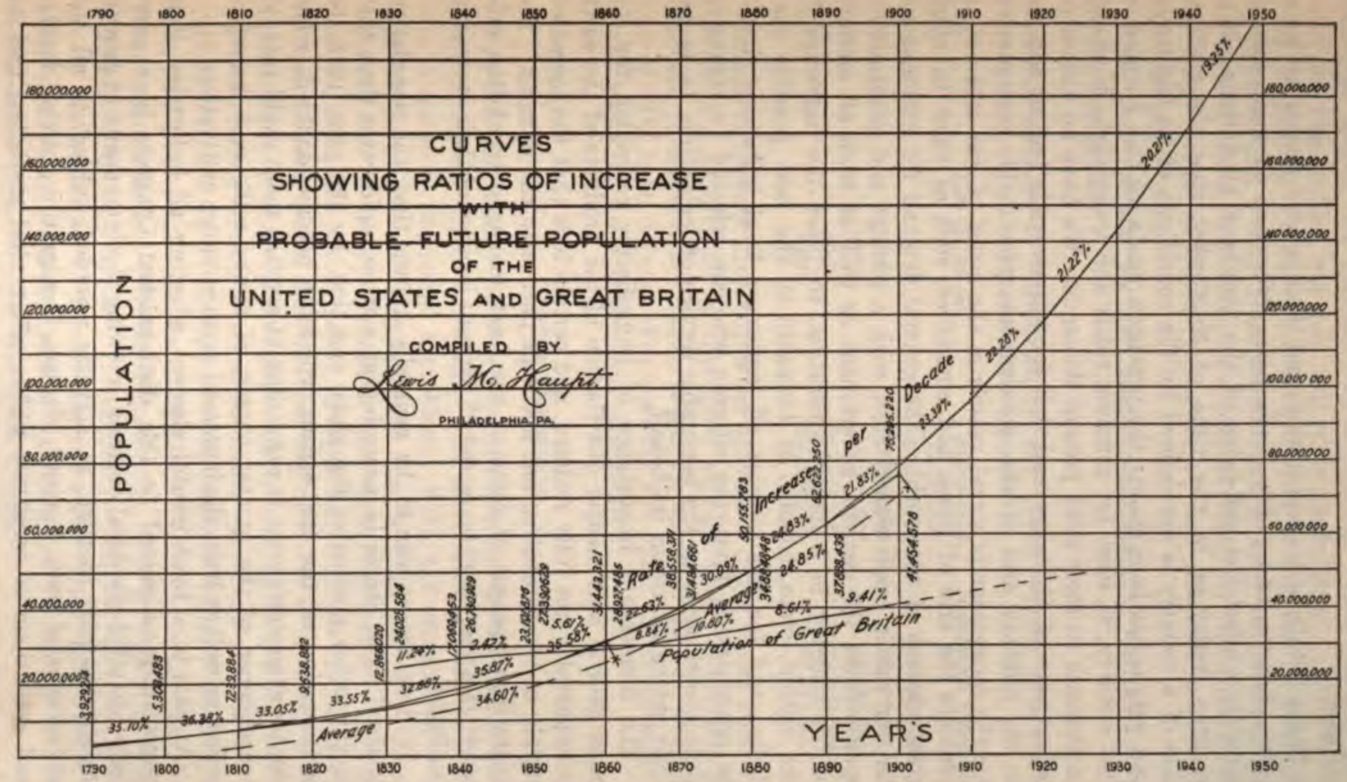
[1] See *The Forum*, January, 1903: *Waterways, An Economic Necessity.*



CURVES
SHOWING RATIOS OF INCREASE
WITH
PROBABLE FUTURE POPULATION
OF THE
UNITED STATES AND GREAT BRITAIN

COMPILED BY
Lewis M. Haupt.
PHILADELPHIA, PA.

upon the basis of payments for results secured, by whatever method.

These details of transportation, and their related factors of legislation, finance, and policy, have been elaborated to some extent, since they affect the well-being of the people of all nations. It is as true to-day as in the time of MacCauley, that the civilization of a country is determined by the conditions of its highways, and yet, as has been shown, the provision made for this purpose in this country, at least for common roads and waterways, is wholly inadequate to meet even present demands. We have no executive department of highways, and that for waterways is but an adjunct to the military arm of the government, presumably inaugurated for the movement of naval vessels in the event of war and not to promote the arts of peace and commerce, such as exist in other great nations of the world. The general demand for national aid for our public roads should meet with a prompt and generous response from the general government as well as from all sections of the country in a local coöperation, to place the highways of the nation, state, county, or township in the best possible condition, and for this purpose all legitimate local influences should be concentrated upon the citizens who are selected to represent their constituents in the honorable service of legislation, to secure their active efforts in its behalf.

The momentous importance of immediately providing for the more general and cheaper distribution of the products of the earth is apparently not fully realized, and certain it is that the increased supply of transportation has not kept pace with the demand. The operating expenses of some of the best managed trunk-line railroads, last year, were increased 25 per cent because of their overtaxed facilities.

It does not appear to be generally known that the population of the United States is increasing at a more rapid ratio than that of any other portion of the globe and that by the year 1935 the enumeration of the last census will have become doubled, while the tonnage movement is expanding at a much more rapid rate, in consequence of the greater output of mines, mills, and manufactories, as well as from the increased acreage under cultivation.

As this is a fundamental element affecting all industries, it is respectfully submitted to this distinguished Congress in a carefully compiled graphical diagram, showing the increments of growth during the past century, as actually recorded, subject to all the vicissitudes of wars, famines, plagues, immigration, births, deaths, and conditions of servitude which affect vital statistics, and to these data the curve of population has been closely applied and its law of evolution determined. It is thus found that the increment per decade has decreased by a constant which reduces any ratio one twenty-first less than that of its predecessor.

By projecting this curve forward, subject to this law of decreasing percentages, a very close approximation may be obtained for the future, which will serve as a reliable basis for the solution of the many social, industrial, commercial, and financial problems, based on population.

Thus there results for the present half-century, the following tabular statement:

PROBABLE INCREASE IN POPULATION OF THE UNITED STATES DURING THE PRESENT SEMI-CENTENNIAL

Date.	*Rate of Increase.*	*Population.*	*Numerical Increment*
1900		76,295,220	
1910	23.39	94,249,201	17,952,298
1920	22.28	115,266,772	21,017,571
1930	21.22	139,703,327	24,436,555
1940	20.21	167,923,399	28,220,072
1950	19.25	200,248,653	32,325,254

Hence it appears that within the lifetime of many of our contemporaries the population of this great republic may reasonably be expected to increase 2.6 times, or 260 %, which is at the average rate of 52 % each decade, thus showing the effect of compounding of the curve due to the decennial increment.

Urban Population

But it is not merely the rapid growth in numbers for which adequate provision should be made. The distribution of the population is quite as important a problem. With the centralization in great communities the engorgement has become not only inconvenient, but at times oppressive and even dangerous. Ferries, trolleys, elevateds and subways, bridges, and tunnels are all taxed to their utmost limits, and the headway of trains is reduced to the danger-point, yet the facilities are wholly inadequate for the morning and evening service between dormitory and shop.

Moreover the daily tonnage of food required to be furnished to man and beast, and the waste required to be removed from the great manufacturing centres, is enormous, thus greatly increasing the risks to life and health. This excessive concentration also leads up to the overcrowded tenements, sweat-shops, and brothels, with their unwholesome environments and immoral diversions; for all of which the most tangible remedy is dispersion.

The density of the population should be held within safe limits by strict sanitary legislation, centres of industries should be established in rural districts, thus requiring shorter hauls for dairy and agricultural supplies and creating local markets for many products. The utilization of waterfalls for the generation and transmission of power to long distances will aid in this effort to distribute the laboring classes to their manifest advantage.

So great is the traffic on the municipal lines that the patronage in many cities exceeds 300 times the total population, per annum, which at times greatly surpasses the capacity of all the cars in the service. There is apparently no relief in sight, excepting the addition of a double deck to the elevated railroads or the introduction of a series of continuously moving sidewalks having different relative velocities, which latter method has been frequently proposed but appears to have many disadvantages, especially in the requirements for space, cost, and freedom from danger and noise.

So long, therefore, as movement is confined to the surface, elevated, or underground roads, the difficulties of handling the traffic must increase in a very rapid ratio unless the population can be confined to smaller local centres or be removed from the surface altogether. This desideratum has given rise to many efforts to construct some practical device for *aërial navigation*, and thus it happens that there is still a medium into which man's ambition would lead him, like Icarus, to soar, were it possible to find some antidote for gravity.

Much progress has, however, been made in the construction of dirigible balloons and special forms of captive kites, which give promise of becoming of commercial value as means of communication and for collecting data, in this rarer medium. It is therefore a part of the laudable purpose of the management of this Exposition to encourage this effort by the awarding of large premiums for the most successful practical efforts. The problem is most alluring because of the manifest advantages to result from its fruition. Instead of having to improve waterways, or to build railways and highways at enormous cost for construction and maintenance, the way would be free to all. There would be no bridges, tunnels, toll-gates, sand-bars, reefs, or other obstacles to the ready interchange of commerce. No custom-houses, forts, or frontiers. Commercial and military barriers would be obliterated and wars would soon become a memory. Were the inhabitants of the earth able to "move like an army of locusts with banners," seeking the garden-spots of the globe, what would become of the Chinese Exclusion Act or the laws restricting pauper immigration? Then would it appear that "the earth is the Lord's and the fulness thereof, the world and they that dwell therein;" for man could seek his own environments much better, and more readily secure the opportunity to earn his bread by the sweat of his face, denied to so many under existing social conditions.

With the inspiring precedent set by Mother Earth herself, floating through an imponderable ether, and held in her courses by the mutual attraction of celestial bodies, and with the wonderful mechanisms of the myriads of beasts and birds constantly mocking the climax of God's creatures, it is not surprising that man should set himself sedulously to the task of surmounting the circumambient clouds and seek to convey himself through a ponderable atmosphere, by flight.

In the mean time the world awaits his efforts with hope and expectation that unknown resources and energies may soon add wings to time and solve the long-desired paradox of aërial navigation.

In conclusion, from this general review of the technological field in civil engineering it will be seen that while much has been revealed and applied in the utilization of the forces and resources of this wonderful planet, there is still much to be discovered. The pregnant past has showered upon this generation coal, oil, and gas; steam, compressed air, and water-power; dynamite and melonite; the turnpike and railway; the palace-car and ocean greyhound; the bicycle and automobile; the telegraph and telephone; and the wizard electricians are now prophesying, like Puck, that they will put a girdle round the earth in forty minutes and will furnish millions of electrical horse-power from a central plant, to any part of the world without metallic conduits.

Quid nunc? Is this only a dream? Who knows? Yet the wheels of progress are ever revolving in an ascending gradient, surmounting obstacles, spanning chasms, uniting continents, eliminating distance, abridging time, and lifting humanity upon the higher planes of consecrated labor to the lofty summits of a Christian civilization.

But to be more specific as to the work before us, it may be said that there is still great need of further improvement in the utilization and transmission of power of all kinds, both by movable and stationary engines; in the application of natural forces to remove and prevent the formation of alluvial bars in commercial channels; in the improvement and extension of better highways for the transportation of materials; in the betterment and standardization of the rolling-stock used in the conveyance of freight and passengers; in the more general introduction of pneumatic plants for the distribution of the mails and for local deliveries in great cities, to reduce the congestion from the delivery-wagons; in the construction of subways for the installation of public-service conduits, sewers, water-supply, lighting, power, drainage, and interurban traffic; in the original provision, in the planning of cities, for all classes of municipal service, prior to the establishment of new strategic, commercial, and populous centres; in the timely equipment of existing towns, in anticipation of the rapid expansion of the population, due to the compounding increment of growth; in additional terminal facilities at points of trans-shipment, to avoid delays and demurrage in port; in the utilization of tidal energy; in continued efforts to attain practical results in aëronautics; and in many other special branches of technology too numerous to mention.

That these desiderata may be attained, it is fundamental that the religious, social, financial, and legislative conditions be made to harmonize by broad and wise laws and statecraft, giving ample opportunities for the utilization of the best-known methods and resources which the country affords, for it is found that law is sometimes a serious obstacle to progress in not keeping pace with nor anticipating the demands of science.

It is not wise to limit our scope to present problems nor confine attention to the fleeting moments. There is a duty which this generation owes to posterity, and it must be met, that history may accord to us the credit of having "builded better than we knew," by laying broad foundations that its pathway be not incumbered by our errors of judgment nor by a narrow cupidity which makes provision only for the passing hour.

Then will the people of our day and generation be true to their heritage, realize their responsibilities, and transmit to the future a basis for still greater aspirations and attainments in the arts of peace and the science of government, that wars may cease and good will prevail amongst the sons of men, for "righteousness exalteth a nation" and "wisdom is justified of her children."

SHORT PAPER

LIEUTENANT-COLONEL THOMAS W. SYMONDS, Corps of Engineers, United States Army, presented a short paper to this Section on "The New Barge Canals of New York."

SECTION B — MECHANICAL ENGINEERING

SECTION B—MECHANICAL ENGINEERING

(*Hall* 10, *September* 23, 3 *p. m.*)

CHAIRMAN: PROFESSOR JAMES E. DENTON, Stevens Institute of Technology.
SPEAKER: PROFESSOR ALBERT W. SMITH, Cornell University.
SECRETARY: MR. GEORGE DINKEL, JR., Jersey City, N. J.

THE RELATIONS OF MECHANICAL ENGINEERING TO OTHER BRANCHES OF ENGINEERING

BY ALBERT WILLIAM SMITH

[**Albert William Smith,** Director of Sibley College, Cornell University. **b.** August 30, 1856. B.M.E. Cornell, 1878; M.M.E. Cornell, 1886; Post-graduate, Cornell University, 1886–87. Assistant Professor of Mechanical Engineering, Sibley College, Cornell University, 1887–91; Professor of Machine Design, University of Wisconsin, 1891–92; Professor of Mechanical Engineering, Leland Stanford Junior University, California, 1892–1904. Member of American Society of Mechanical Engineers. **Author of** *Materials of Machines; Elementary Machine Design*.]

THE problem of educating young men to take up the world's work in engineering is a continually changing one. Engineering continually increases in scope and complexity and keeps demanding better trained and wiser men for the solution of its problems. What are the technical schools to do to meet this demand?

Engineering is not an exact science; the sum of knowledge on which it rests is too meagre for exactness. Many of the factors of an engineering problem are susceptible of exact determination from known facts and mathematical deductions; others can be approximately estimated; while others still are elusive and prone to hide themselves, often successfully. Many a man has based an engineering work involving the expenditure of large sums of money upon an analysis in which one factor has eluded the "round-up." Then when money was spent, when the idea was in cold metal, this little cold-blooded factor came out, pointed a condemning finger at the man and said: "This won't do, you forgot me!"

I wish to make a slightly adapted quotation: "The mathematician in solving a problem takes into account all the factors that appear; the engineer must consider all the factors there are." The work of the engineer must not fail, or destruction of human life and property results, and he is criminally responsible. He must consider all the factors there are!

As the sum of knowledge grows it becomes quite complete in certain divisions of engineering work. Then factors of safety are reduced, standards are designed, and the work may be done by any one who can learn a routine and can follow it repeatedly with accuracy. But the real engineer has nothing further to do with it, unless new applications are demanded.

But most engineering work reaches into unexplored or partially explored fields, and in such cases the last appeal is to the judgment of some man. In other words the real engineer is a man of trained judgment. It is impossible to teach any general method for the solution of engineering problems. No two are alike; the modifying factors are so many that the possible number of combinations is indefinitely great and the same combination seldoms recurs. A man's judgment must be trained so that he can take any combination and reach a good solution; not necessarily the best solution, for there may be many good solutions differing only slightly in results.

Judgment for its training must draw from many sources. There must be the understanding of the mathematical basis of all engineering; a knowledge of inorganic nature's laws and of the qualities of engineering materials and of constructive principles; and all this the schools ought to supply. But there must also be the experience which comes from being "up against the real thing" with no authority at hand to appeal to — when there is just the man and the problem and the necessity for a result. This is the kind of experience which tries men's souls and makes engineers — or failures. It cannot be supplied by the schools.

There has always been a gap between the technical schools and the practice of engineering. Thirty years ago when practice was simpler and the schools cruder, this gap was wide. In those days engineering firms and manufacturers did not seek to employ technical graduates; they said: "We have tried them and they always try to shift a belt on the wrong side of a pulley; we prefer to train up our own men." That this gap has narrowed somewhat is shown by the fact that men in authority in three prominent engineering and manufacturing firms came to Cornell last June to meet members of the graduating class with a view to engaging young men for their work, and this same thing happens at other schools. But still there is the gap; the graduate must still unlearn some things that have been improperly taught, and must learn other things that have not been taught at all. There must of course always be a period of readjustment because the conditions in practice and in the schools can never — from the nature of the case — be the same.

To meet the demand therefore the schools must cease to teach wrong things, and must teach right things.

The development of engineering, with the accompanying development of the engineering schools, has been a very interesting process. Out of the "chalk age" has come the orderly present practice. In the chalk age a man would go into his shop with an idea in his head and a piece of chalk in his hand; he would clear off a place on the work-bench and call up his best man. He would sketch and explain and when asked about dimensions would take out his two-foot rule and slide his thumb along it till he reached the right place and chalk it down. Then the best man would look in the scrap-heap for available parts; would interview the pattern-maker and the blacksmith; and later there would be a machine. This machine would be tested; parts that failed would be replaced by stronger ones, motion ratios would be adjusted, and finally the machine would perform its function, all honor to the fine men who did this work. But this process of machine evolution was tedious and expensive, and the chalk man often wished he could figure out dimensions because he saw profit in getting things right the first time. It was in response to many such wishes that the technical schools appeared. But they did not spring full-armed into being. Like other earthly things they have developed by orderly growth. The law of survival of the fittest operated as in organic evolution; unfit things have fallen away and have been replaced by fitter ones, while much that was good has survived. From the first it was clear that an engineer should understand the laws of inorganic nature and the relations of numbers, and hence physics and chemistry and mathematics were included in the early courses. But the use of shops for the training of engineers does not seem to have been grasped, for students in most cases were simply taught handicraft. One exception was the shop in which Professor Sweet taught not only skill with tools but also principles of construction, together with the highest ideals in machine design. But Professor Sweet is such a man as comes but once in a generation or two.

Many of the technical courses were grafted on the existing college courses and an attempt was made to combine a liberal and a technical training. It does not need to be stated that these schools were inadequate even in the simpler state of engineering; and yet — out of these schools came many of the men who have helped to bring engineering to its present advanced state. But that was because they had power to bring what they had learned into action, to supplement it by wisdom gained in practice; in other words, to train their judgment till they became real engineers.

In contrast to this is the present state of the technical schools. Engineering has developed steadily and the schools have tried to meet its demands; not with perfect success, but still successfully.

One of the difficulties ahout technical schools is that the teacher by the very fact of teaching is put out of touch with his profession; and the profession advances so rapidly that in a few years he is side-tracked. He teaches engineering as he knows it; but that is not as it is.

Some teachers who are fortunately placed combine consulting work with teaching, and if a nice balance can be maintained this must give good results. There is always, however, a temptation to give too much attention to the consulting work with its strenuous demands and to slight the teaching.

It would seem that the ideal way is to spend alternating periods of a few years in teaching and practical work. This has been done in several cases on personal initiative with good results; and in at least one institution it now has the approval of trustees, president, and faculty.

If a man had just spent three years in advanced practice in engineering what would he find to criticise in any one of the many good modern American technical schools?

Let us consider this briefly in detail.

Mathematics. The devotee of pure mathematics delights in abstract processes. We have all heard of the toast offered at a banquet which concluded a congress of mathematicians: "Here's to Higher Mathematics, may she never be degraded to any human use." This was only half-meant.

I know a man who says that a mathematical question loses all interest for him as soon as it proves to have a practical application. His feeling is right; the work of his kind has been of infinite service to humanity, but he is not of the stuff of which engineers are made.

The mathematical subjects in technical schools have always been taught to engineers by mathematicians and they have very naturally presented and emphasized the things that had greatest interest for them. These are not usually the things of most use to the engineer. In some cases, no doubt, such teachers have resented suggestions as to their teaching; but in most cases I believe they receive suggestions gladly and are anxious to do all in their power to make their service most efficient. I believe we are to blame who have allowed suggestions to be lacking. He who has spent any considerable time in modern mechanical engineering work knows that for most of the figuring only a knowledge of the elements of the mathematical subjects given in the technical courses is needed. But it must be a *working knowledge.* Occasionally a problem arises requiring more advanced knowledge for its solution. Why not then apply to what Mr. A. P. Trotter in a recent paper calls a "tame mathematician" for a solution which can be applied by the engineer. If a man can be an expert mathematician and an able engineer also, it is a fine thing; but most men cannot because of the time-limit to life.

It would seem that the trouble with the teaching of mathematics for engineers is that it goes too far and not deep enough. It is a working knowledge of elements that the engineer needs. Why not drill him till he can use the elements as he uses arithmetical processes, and leave the advanced work to the pure mathematician?

Shops. The object of a shop-course in a trade-school is to teach handicraft to one whose life-work is to be in the shop. The object of a shop-course in an engineering school is to give an understanding of principles of machine construction to one who needs such understanding to be a successful engineer. Obviously the method should be different in the two cases. In the first case it is of great importance for the student to chip and file an exercise-piece so that it exactly fulfills the specifications; in the second case it is of very little importance.

A student cannot learn four trades working six or nine hours a week for nine months during each of three years; but he can learn in that time — if properly taught — much of machine construction which will help to make him a better engineer.

In the machine-shop all exercises that are for the training of the hand alone should be dropped and the student should learn the operation of every machine tool; he should be led to put each to its maximum safe output, so that he may grasp something of the meaning of economic production. He should be taught the methods of producing duplicate parts in large numbers at low cost. He should learn something of the shop organization and arrangement for minimum cost for handling; he should learn something of shop lighting and sanitation and its bearing on the cost of product; he should learn something of the methods of reward by which workmen are led to increase the shop output and their own incomes; he should learn about accurate and simple cost accounting and its economic results.

In the pattern-shop the making of ornamental vases and inlaid boxes should be excluded and the student should learn the best methods of pattern-making, and to distinguish between the allowable expense of a pattern made for one casting and a pattern made for many castings; he should be shown all the short cuts that save labor in the pattern-shop and the foundry.

In the foundry art-casting should cease and the student should learn the methods of green-sand, loam, and sweep-work, either by the actual execution or by explanation with models; he should do snap-flask work and should see moulding-machines operated; he should learn economic methods of handling raw material and the product in large foundries; he should know how to make charge mixtures for different results and should study cupola and air-furnace operation for best product.

In the smith-shop artistic forging should be excluded and the student should learn not only simple forging, tool-dressing, and heat-treatment of steel; but he should also be introduced in the production of duplicate parts by drop-presses, and in the methods used for the production and annealing of large forgings.

This is not too high a standard for the shops of an engineering school; its realization will increase the value of the schools to practice and hence it will come. Obviously it involves great changes in existing methods. Shop-talks and class-room work must supplement actual work because so many principles are involved, and the actual work must be greatly modified. Already many of the schools have made a start in this direction.

Drawing and Design. In drawing all art-work should be excluded, and the student should learn to make neat and clear-dimensioned sketches and accurate, well-executed working drawings with good plain lettering.

In machine design the theory has long been well taught; but the modifications of design in response to the demands of practical every-day considerations have usually been neglected.

Experimental Work. The prime function of the undergraduate mechanical laboratory is to teach men to test the efficiency of machines, the secondary function is to afford opportunity for research. Many will object to this order because research is undoubtedly the higher work. For a post-graduate laboratory the order would be reversed; but for an undergraduate the thing of first importance is to learn methods of testing. If in addition to that he is able to catch something of the investigator's spirit it is fortunate; but in most cases it will be but little; there is n't time. Moreover, the investigator and the engineer belong to different classes.

The engineer is he who conceives and materializes ideas that help humanity harness nature for its use. The investigator is he who extends the field of knowledge. This is not an absolute division, for many engineers find out lacking facts for their own use, and many investigators apply the facts they have determined; but in general the classification holds.

Once in a while there comes a student with the investigator's spirit; he is born to add to human knowledge. He is to be cherished and encouraged; if he shows a tendency toward engineering work, the brakes should be applied. The world has many engineers and few investigators, and the few cannot be spared.

The mechanical laboratory, although a comparatively recent addition to the technical courses, is very efficient in most of the schools. This is probably partly due to the fact that the induce-ment for teachers to keep in touch with practice is greater through consulting work than in the other departments. The criticism of the man just out of practice upon the mechanical laboratory would probably be that things are arranged too conveniently. A machine or a series of machines is made ready for operation, and the student makes certain observations from which he deduces results. In some cases he is not even allowed the responsibility of operation. In practical testing it is the getting ready that needs the engineer's best ingenuity and judgment and effort.

Steam Engineering. The tendency in this work has been too much to go far into theoretical thermo-dynamics. This is usually "over the heads" of the average undergraduates. What the engineer needs is a working knowledge. The thermo-dynamic theory which suffices for this is not difficult, but it needs to be thoroughly understood. Again it is better to go deeper and not so far. Also the economic part of power development should be emphasized. It is not so much producing a maximum result per pound of steam as producing a maximum result per dollar cost.

These are criticisms in detail. What would be the criticism of the course as a whole — of the spirit of the place? In general it would probably be that the school needs to "get in line" with practice. The student coming out should not need to turn even through a small angle but should go straight on. Some details may illustrate:

Engineering work is done because it is paid for, and no solution is right which ignores the money factor. In the operation of any mechanical engineering installation, there is cost of labor; cost of supplies, including energy; cost due to depreciation; cost due to interest on first cost; cost of repairs; cost of probable delays; cost of taxation and insurance.

There may be many combinations of machines and apparatus that would give the required result, and each combination might vary all cost items. The engineer must determine the combination that would give the least sum of costs. It is believed that the schools are apt to consider economy of elements rather than of aggregates, and to neglect variations due to local conditions. This is not in line with practice.

Another thing that is not sufficiently emphasized is the judging of results by their reasonableness. I quote from a recent address to the graduating class of Stevens Institute by Mr. Walter C. Kerr: "This again is a thing which each man does for himself in his own best way, and its essence consists in asking one's self whether the thing is reasonable. It is a great check upon error. It applies equally to nearly everything of which engineering is composed. It is the power of the human mind, after performing in more or less systematic and conventional ways, to stand off and look at results and ask one's self whether they are reasonable. One man will figure that certain material weighs two hundred tons, and believe it. Another will say that there is something wrong in that, for it all came in two cars."

The engineer in practice has to check results in this way because errors are costly in money and reputation; but in the school where ideas are not materialized the result of errors is less serious. The consequence is that it is customary to assume that a result is right because it has been figured. To use another illustration: One man may get a result by using seven-place logarithms and may say that it must be right because of the seven places. But another may check it through with a slide-rule and show a large error in the second figure of the result. After working out in detail, the whole problem should be looked at broadly for reasonableness. The schools should lead the student in this direction to line up with practice.

These are probable criticisms of a man fresh from practice. Every practicing engineer will, I think, recognize their reasonableness.

Who then are the men to work out the changes? The men with teaching capacity fresh from practice; and so again we come to see the desirability of alternating teaching and practical work.

Another difficulty is the present time-limit of the technical course. With engineering development has come the demand that the engineer should have broader training. The course was made to cover four years at first, and that served for the early days; but now for years we have — so to speak — been blowing steam into a closed vessel from a high-pressure source; the result is too high pressure. Students are worked too hard and as a result cannot do the best work of which they are capable. It takes time for ideas to soak into the human brain. The solution is to increase the course to five years. The objection usually made is that students cannot afford the time and expense. But is this true? I know a man who spent ten years after entering college before he began the practice of medicine; four years in college, four years in the medical school, and two years in hospital work. This may be an extreme case, but this is the kind of a physician I would like to call in case of serious illness. Suppose the student leaves the technical school at the age of twenty-four. He may reasonably look forward to thirty-six or more years in the practice of his profession. If an additional year's study can increase the efficiency of each one of these years, is it not worth while? The increase in efficiency is not due alone to the additional year's work. The stress is reduced, and the development is more normal. Moreover, the danger of mental overstrain is reduced. The five-year course also would give opportunity for the introduction of outside work that would increase the engineer's power: elementary economics and transportation problems; elementary law and contracts; with a great deal more English composition and theme-writing.

The student will say that his father will not give him five years at the university. How about his brothers and friends who study law or medicine? We have only to get used to the idea. I believe the five-year course will come within the next five years.

In this same connection is another point. An engineer's success is increasingly dependent on his ability to meet men of refinement and culture on their own plane. Obviously there is no time in a technical course for culture studies. For fifteen or more years there has been a tendency for a few men who have completed an arts course to take two or more years in engineering. This is a tendency to be encouraged, for it makes for increased power and efficiency in engineering. We ought to get into the habit of thinking of the technical school as a professional school to be entered only on the completion of the broader general course.

There is another criticism which has come to me many times from men in different grades of practice. The technical schools are organized so that a young man who has passed regularly through the public-school system finds entrance easy; while maturer men whose schooling has been irregular, but who have had several years of practical work in lines connected with engineering, find entrance difficult. Yet the latter class are apt to have greater capacity for becoming engineers. It seems certainly necessary to require that all candidates shall have the mathematical preparation. It is impossible to build without a foundation. But any earnest man with engineering capacity can get this preparation. It is other subjects that give trouble. If a man has spent several years in a shop or drafting-room, or at some other work directly connected with engineering, he certainly has increased his understanding of what engineering training should be; he has usually very much greater earnestness for study than the young man from the high school. In other words his work has been effective preparation for a technical course. There should not be any difficulty in giving value to such work toward entrance.

This problem may be solved as follows: Make the mathematical and English requirements rigid. Let the other requirements stand as at present, but add to them shop-work, drawing, and such other subjects as may be judged to give equivalent training. Let a certain number of these subjects be required with free election. This plan is now in successful operation at Stanford University.

Some desirable men (I have known many of this class) might still be unable to enter. If they can offer the required mathematics, they may be admitted as special students. This would bar them from taking degrees, and this might seem a hardship if degrees are really of any value. This difficulty has been overcome at Stanford University by allowing a man who has entered as a special student to graduate by making a total of one hundred and fifty hours; that is by taking an extra year's work. This is of course simply making a man with defective entrance training take a five years' course for a degree.

After the technical school has done its full duty by a young man his education is only begun; he must spend years in contact with practice before he can attain that ripeness of judgment which will enable him to say of engineering schemes, this is right and that is wrong; before he can reach his full power as an engineer.

SHORT PAPERS

Mr. H. L. Gantt, of Providence, Rhode Island, contributed a paper to this Section on the "Application of Scientific Methods to the Economic Utilization of Labor."

Professor James E. Denton, of Stevens Institute of Technology, Hoboken, New Jersey, read a paper on "The Best Economy of the Piston Steam Engine at the Advent of the Steam Turbine."

SECTION C—ELECTRICAL ENGINEERING

SECTION C—ELECTRICAL ENGINEERING

(*Hall* 10, *September* 22, 3 *p. m.*)

SPEAKERS: PROFESSOR ARTHUR E. KENNELLY, Harvard University.
PROFESSOR MICHAEL I. PUPIN, Columbia University.
SECRETARY: MR. CARL HERING, Philadelphia, Pa.

THE RELATIONS OF ELECTRICAL ENGINEERING TO OTHER BRANCHES OF ENGINEERING

BY ARTHUR EDWIN KENNELLY

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ENGINEERING is coeval with civilization. Its crude beginnings must have evolved with the first banding of men together for a common purpose. In a very broad sense of the term, engineering comprises all material construction and operation executed by a community through the efforts of a specially selected few. The degree to which engineering is carried in a community is a measure and criterion of the degree of its material civilization. *Ex pede Herculem.* The pyramids of Ghizeh and the Cloaca Maxima at Rome clearly reveal by inference the status of their respective communities at the dates of those constructions.

In the same broad sense, engineering lays every art and science under contribution. But whereas the branches of engineering dealing with architecture, mechanics, mining, ship-building, road-making, and hydraulics go back to prehistoric times, steam engineering and electrical engineering are of comparatively recent date, steam engineering being about two hundred years old and electrical engineering about seventy. These youngest branches of engineering have completely changed the aspects of the parent tree. Without them modern civilization could not exist.

Each new industrial application of electricity has opened a new field for electrical engineering. The electric land telegraph first opened commercially in 1835. The electric submarine telegraph commenced in 1850. Since 1870 the electric dynamo and motor, the electric telephone, the electric arc and incandescent light, the electric furnace, the electric railway, and the electric wireless telegraph have all come into existence. These industrial applications have jointly created an applied science and an art with a large and rapidly growing literature, language, and technology. In the United States alone it is estimated that these industries have a total investment of three billions of dollars and employ 400,000 workers.

The most significant difference between electrical engineering and all other engineering lies in the fact that electrical engineering deals with the application and control of wave-movements propagated through the universal ether with the speed of light; whereas all other engineering deals with the mutual relations between material substances. In other words, electrical engineering is the controlled operation of the immaterial upon the material. All other engineering is the controlled operation of the material upon the material.

A projectile may be fired from a cannon over a thirty-kilometer range at an initial velocity of about one kilometer per second. A locomotive may be driven over a smooth level track at a speed of fifty or sixty meters per second; but an electric impulse will travel over a wire at a speed of 300,000 kilometers per second. Both the projectile and the locomotive must displace the air through which they move, producing violent frictional disturbance of the medium. The electric impulse moves through the air without friction or appreciable disturbance. Hence the wonderful adaptability of electricity to play the part once assigned to the winged Mercury among the gods on Mount Olympus, and by its enormous speed to annihilate distances.

In nearly all industrial electrical applications, energy is transmitted over wires, and it is the transmissibility of electrical energy which gives its principal value. The energy is transmitted from convenient sources, or points of generation, to sinks or consumption points, where the energy is abstracted and converted. In some cases it is directly converted by electric motors into mechanical work. In other cases, it is converted into heat, as in electric furnaces for heating, or in electric lamps for lighting. In yet other cases it is converted into mechanical energy, not for doing work, but for communicating intelligence, as in the telegraphic receiving-instrument. But in all these cases the electric energy is carried to the point of consumption and delivery through the ether, guided by the wire or wires. The interior of the wire is the only place where the transmitted energy does not flow, for whatever energy enters the wire is wasted therein as heat, and fails to reach its destination.

Prior to the introduction of the steam engine, men worked in two ways; first, as intelligent beings exercising skill and judgment; second, as muscular machines, or peripatetic sources of brute force, like beasts of burden, with vestiges of intelligence. This segregation of a large section of the people into competition with animals tended to brutalize all men, both the muscular machines and the more intelligent beings over them. Coal and the steam engine gave a great lift to humanity by removing the competition of human muscle with brute muscle. The applications of electricity have so far aided the uplifting process, by the improved distribution of power, that not only are men emancipated in civilized communities from draught-service or mere animal-haulage; but even horse-haulage in large cities has commenced to be uneconomical.

From an economical standpoint, electrical engineering coöperates with other branches of engineering in distributing either special utilities exclusively, or general utilities with particular advantages. Distributions of the former class are intelligence and power. Distributions of the latter class are light and heat. That is to say, the telegraph and telephone maintain a monopoly of the rapid transmission of ideas. The electric motor has almost a monopoly of the distant transmission of power. But electric light is in competition with other forms of illuminant, and maintains its present position by virtue of convenience, cleanliness, or other special qualities.

The sociological advantages derived from the electric telegraph and telephone are enormous. If, as has been claimed, the invention of the logarithm-table has virtually doubled the lives of astronomers, the invention of these electric implements has virtually doubled the lives of business-men. Moreover, our modern systems of government would be impracticable in the absence of these instrumentalities. It is stated that in the year 1815, prior to the electric telegraph, the news of the battle of New Orleans was not received in the national capital, Washington, for three weeks. On the other hand, in 1898, the news of the battle of Manila was reported in Washington a few hours after it occurred, by actual time; or, some hours before it occurred, by local Washington time.

As regards the electrical distribution of power, the convenience with which insulated wires may be carried and distributed to motors in and among buildings has profoundly affected the construction and operation of modern factories, where the long overhead rows of constantly running countershafting, with large numbers of endless belts thence descending to machine tools, has been replaced to a considerable extent by a clear headway for cranes, and an electric motor on each machine tool or near to each group of tools. The complete control of tool-speed which this system provides and the cessation of all waste of power in running friction when a tool is out of use, are great advantages in favor of electric factory driving.

The contrast between the transmission of power by electricity and that by rope-haulage is very remarkable. A steel cable in a rope-drive can transmit say 300 kilowatts (about 400 horse-power) to a distance of a few kilometers by its bodily movement at the rate of a few meters per second. On the other hand, a quiescent electric cable of copper, suspended on the insulators of a pole line, can transmit 3000 kilowatts to a distance of a few hundred kilometers, with about the same efficiency. In the case of the mechanical transmission, the wear and tear and depreciation of the steel cable is considerable. In the case of the electric transmission, the wear and tear of the conductor has never yet been detected. The depreciation is practically limited to that of the poles, insulators, and mechanical supports. So far as is yet known, an electric conductor does not wear out electrically by the exercise of its functions.

At the present time, the longest commercial electric power transmission is in California, from de Sabla water-power house, in the foot-hills of the Sierra Nevada, to Sausalito, opposite San Francisco, a distance of 232 miles (373 kilometers); while 7500 kilowatts (10,000 horse-power) is regularly transmitted from Electra, another water-power house in the Sierras, to San Francisco, a distance of 147 miles (236 kilometers). It would seem as if it were only a question of time when every important waterfall shall be harnessed to turbines and dynamos for the transmission of solar energy to the nearest mart.

Up to the present time, the coal-supplies of the world have kept us amply furnished with power at low rates. With coal averaging say $2.25 per metric ton in the Eastern United States, the cost of a kilowatt-hour at the steam-engine shaft during the working hours of the year is from 1.75 cents in small plants to 1.33 cents in larger plants, with good management and economy. It is estimated that the world's total output of coal is approximately two millions of metric tons daily. At the present rapidly increasing rate of consumption, the cost of coal delivery tends slowly to increase. Unless, therefore, discoveries are made of new available sources of power, the value of solar power may be expected to appreciate. The only solar engine of large power that has thus far been made effective, or which promises to be effective in the near future, is the waterfall. Already several hundreds of thousands of kilowatts of the world's water-power are electrically converted from waste to utility. In the single instance of Niagara Falls, about 100,000 kilowatts are already utilized, and plans now in progress promise to develop a total of about 500,000 kilowatts more. This electrical power is sold to consumers in the vicinity of the Niagara power-house at about a quarter of a cent per kilowatt-hour, in large quantities, continuously.

One of the greatest advantages which electrical engineering has rendered and is rendering to the people is in cheapening and accelerating transportation by the electric street-car and railroad. In a number of American cities it is possible to travel for five cents any distance in one direction up to 10, 15, or even 20 miles, at a schedule speed of from 7 to 12 miles per hour, and with cars on headway of from 2 to 15 minutes. The reason for the cost of transportation being so low is that the electric street-car is easily controlled, can be started and stopped at small expense, and requires no private roadbed or right of way. The effect of this reduction in time and cost of transportation is to increase the available area and diminish the density of urban population. This rapid transit acts as a distinct check to the modern tendency of overcrowding city districts. It averages more nearly the values of real estate and improves hygienic conditions. In 1902 the number of passengers reported to have been carried by the steam railroads of the United States was about 600 millions; while those carried by the electric railroads was about 4800 millions; or eight times as many. The average steam-railroad distance of travel was 30 miles for a fare of 60 cents or very slightly over 2 cents per mile. The average electric street-railroad fare was very nearly 5 cents. The electric railroads carried the entire population on the average 63 times during the year; while the steam railroads carried the population nearly 8 times. But whereas the steam railroad passengers carried had increased only 5 % in the decade prior to 1902, the electric passengers carried had increased 137 % in the same time.

Not only has the electric railroad given cheap and convenient urban and suburban traveling; but it has also largely removed the preëxisting discomforts of such travel due to dust and smoke, so that electric railroad traveling is frequently resorted to for pleasure; while steam railroad traveling is usually only resorted to for reaching a destination.

From a constructive standpoint, electrical engineering has had a marked beneficial influence upon other branches of engineering. For example, it has developed the capacity of steam and hydraulic prime movers. The largest stationary steam engines and the largest hydraulic turbines have been called into existence by the demand for electric power distributions. The high-speed reciprocating steam engine was developed to meet the requirements of dynamos. The most recent and highest speed type of steam engine — the steam turbine — could hardly have been utilized or developed for stationary work in the absence of electric power plants. These steam turbines, while only of very recent growth, offer a working efficiency comparable with that of the best reciprocating steam engines; while they have markedly reduced the expense of material, construction, floor-space, foundations, and operation. At the present rate of progress, it would seem as though the reciprocating steam engine would eventually be superseded by the rotary steam engine. Conversely, this improvement in steam engineering is reacting to the benefit of electrical engineering by reducing the size and cost of steam dynamos and the price of electric power in distributing-systems.

The development of any one branch of engineering inevitably stimulates other branches. The reduction in the cost of electric power for machine-driving thus promotes activity in the construction of all kinds of machinery.

The development of electrical engineering has also tended to increase the accuracy and precision of other branches of engineering; first, by simplifying the delivery and measurement of power, and second, by the introduction into engineering of a scientific system of units.

Mechanical power is delivered from one body or system to another through mechanical contact, or the pressure of one material system upon its neighbor. In general, the power transmitted is equal to the product of the effective pressure, or tension, and the velocity at which it is delivered. In most cases it is very difficult to determine the magnitude of the effective pressure. In the electric transmission of power, the power is delivered through an electric conducting circuit, and while in the circuit is equal to the product of a certain voltage and a certain current strength. This product — the electric power — is readily capable of precise measurement. Consequently, the most convenient and accurate method of measuring the delivery of mechanical power is usually by electrical means through the intervention of an electric circuit. Thus the power which a machine receives from moment to moment in the performance of its duty, or the total energy which it receives in the course of a given period of time, may be determined with great convenience and a high degree of commercial accuracy by electrical measuring-instruments placed in the circuit of a motor coupled to the machine. By the accumulation of such observations and experience the knowledge of the behavior of machinery has been greatly augmented since the general introduction of dynamos and motors.

It is a remarkable fact that in spite of our lack of knowledge as to the precise fundamental nature of electricity and magnetism, the knowledge of their action and control should already be so definite and precise. In many instances it is possible to design and predetermine the behavior of electric machines as closely as it is possible to determine their behavior experimentally after being built, under commercial or factory conditions. That is to say, a skilled designer, accustomed to a certain class of dynamo machines, can frequently compute the characteristic properties of a new dynamo or motor, as laid out on paper, to as close a degree of accuracy as those properties can be measured, under commercial conditions, after the machine takes material form. This general precision of electrical engineering has aided engineering in general to become an exact science.

Electrical engineering has adopted by international convention a system of electromagnetic units which is based upon the international metric system, and which has the advantages of being simple, decimal, and international. This has tended to give precision and definiteness to all electrical engineering measurements. In other branches of engineering, the custom varies in different countries. Thus, in hydraulic engineering, the cubic foot (of water), the cubic yard, the short ton, the long ton, the metric ton, the liter, the British gallon and the U. S. gallon are all promiscuously used in such a manner that measurements in one country are frequently unavailable to engineers in other countries without lengthy arithmetical reduction. This is a most unfortunate diversity. Again, in mechanical engineering, the foot-pound-per-second, the foot-ton-per-second (long and short), the British horse-power, the European continental horse-power, the poncelet, and the kilogramme-meter-per-second, are all in use as units of power. Unless qualified as to standard geographic latitude, they are all subject to variation within a quarter of one per cent above or below the mean, owing to the variation in the force of gravitation with terrestrial latitude. On the other hand, the electric unit of power, the watt, is independent of the latitude, or even of the planet, and besides being an international mechanical unit, is also an electrical circuit unit. For these reasons the kilowatt (1000 watts or about 1⅓ horse-power) is at present steadily displacing the horse-power in engineering literature, all over the world.

Electrical engineering has exercised a marked intellectual influence upon the time, in the direction of mathematics. Applied electricity is particularly subservient to simple mathematical law, which is but another way of stating that the present applications of electricity are well understood. Prior to the development of electrical engineering, the useful applications of mathematics to engineering were almost limited to mechanics, statics, and kinetics. Now, electrical engineering has thrown open to application the entire stock of mathematical physics which has been accumulating for several centuries. Consequently, it is now not only difficult to find a department of mathematical science which does not have applications useful in engineering; but engineering has also found, and is constantly discovering, new fields for profitable exploration by the mathematician. In the last few decades, departments of mathematical analysis which had previously been regarded as pure, or inapplicable, are now strained to their known limits for giving practical service to engineers. Moreover, there are many directions in which engineering would be applied, if mathematics could only gain a reliable foothold on the outcrop.

In any new application of science, first comes the fact discoverer, then the mathematician, who quantitatively connects the newly discovered phenomenon with the known environment. Next in succession is the inventor, who grasps the utilitarian possibility of the fact; then the engineer, who grasps the essential portions of the already enunciated mathematical law, and relates the same to commercial and constructional conditions. Finally, the capitalist grasps from the engineer the commercial limitations of the reduced law and estimates the commercial values of the utility, venturing capital upon the new possibility on the risk of its desirability or undesirability. In rare cases it is possible for any successive number, or all of these intellectual stages to be reached in one and the same individual; but it seems to be a general sociological and intellectual law that the capitalist will not risk the savings of past labor on a new application of science until the engineer has intellectually assimilated the problem from an arithmetical standpoint, with due regard to physics and mechanics on the one hand and to the cost of factory processes on the other. In his turn the engineer is often unable to grasp the problem arithmetically until the mathematician has intellectually apprehended and elucidated the quantitative scientific relations of the problem to a reasonable degree of completeness.

Thus, for example, considering the modern dynamo, first came the discovery of the phenomenon of electro-magnetic induction by Faraday; then the work of mathematicians, like Ohm and Ampère, to determine the quantitative relations of the phenomenon to the known cosmos. Thus far the matter was pure science. Then came inventors who conceived the idea of utilizing the new principle for the industrial generation of electricity. Unless, however, the inventor was himself an engineer or was assisted by an engineer, the idea would have been practically unavailing, however important the idea might be in directing attention to the possible use of the new phenomenon. The work of the engineer was next necessary to design the machine. This he could only do effectively according to his apprehension of the mathematical, physical, and mechanical underlying laws already discovered, and the application of those laws in such a manner as to fit factory methods of construction economically. Then came the capitalist ready to venture the accumulated savings of the community he represented, upon the project of building dynamos for commercial purposes, as soon as he was satisfied as to the commercial desirability and economy of the new process.

In reality the modern large dynamo has had to undergo many such successive stages of intellectual and material preparation, in order to reach its present stage of development. Frequently the capitalist would have preferred to install larger dynamos than existed at the time, but could not risk their being unduly enlarged because the engineer could not be sure of the results, and the engineer could not see his way clear for want of existing scientific and mathematical knowledge in the direction considered.

Although the above sequence of relations is generally admitted to be self-evident on consideration, yet the perception of these relations by the community at large seems to be a matter of social and economical importance; because the more clearly that organized society apprehends the steps of the processes by which it ultimately secures what it needs, the more effectively it is likely to stimulate the activities which lead to those steps. It is of importance to the whole world that there should be an adequate distribution of activity in all these stages of effort to secure new gifts from nature. There should be plenty of work in physical and scientific laboratories for the discovery of new facts. There should also be plenty of mathematical work carried on to interweave and connect these facts with the great universe of quantitative relations. There should be plenty of stimulus and reward for inventors to find useful applications for the new facts. There should be plenty of engineering work devoted to controlling the facts by reducing the purely mathematical relations of all time to the commercial mathematical relations of the locality and momentary time. Finally there should be abundant opportunity for the business-men acquainted with the needs of the community to ascertain the results and possibilities of engineering development as well as adequate reward for the successful investment of capital in such enterprises as they consider the engineers can offer and the community will accept.

In line with these ideas it is found that even to-day large industrial corporations finance new scientific applications in their line of work, maintain their own corps of engineers and inventors, and their own research laboratories with scientific experts. Already, therefore, these corporations consider that it is economically desirable to develop simultaneously in their own body all these successive stages of intellectual and material effort. If this be the trend of individual engineering industries, it is reasonable to expect that the future trend of larger communities will be in a similar direction. That is to say, cities or nations may in the future consider it economical to foster either directly or indirectly any or all of these stages of intellectual activity which conjointly lead to new material wealth, on the principle that properly organized activity for any purpose is more effective than spontaneous sporadic and disorganized efforts of individuals in the same direction. Wonderful possibilities lie before organized scientific research and organized creative engineering based upon the same.

From the psychological standpoint, electrical engineering has come to exercise a marked influence upon civilization. These psychological conditions are important, because if we compare the condition of the world to-day with that which is reflected to us from the history of past times,we are impelled to recognize that there are two salient differences between them. One is the increase in later times of material wealth, including processes, utilities, and conveniences, such as steel structures, the railway, or the printing-press. The other is the change in the general mental attitude of human beings toward each other and toward their surroundings. That is to say, one salient change is material in its nature; while the other is psychological. It cannot be denied that both are of great importance to the progress of civilization, and perhaps the one is as important as the other. The attitude of mind of the ancient Egyptians, as reflected in their writings and remanent structures, must have been markedly different from that of the Greeks in the days of Homer, or from that of the Romans under Nero, or from that of Europeans during the Middle Ages, or from that of the peoples in the modern civilized world. In a certain sense, the psychological condition reflected in a community transcends in importance its material conditions. The development of a worthy and potent psychological condition in a people is even more important, from this view-point, than the development of a great and ample material condition. The one is probably necessary to a highly developed state of the other.

The effect of electrical engineering applications on the psychology of the community has been greatly to extend the radius of mental influence of the individual. In the days before the discovery of written language, the intellectual sphere of influence of an individual was limited in radius to that distance at which his voice could be heard. Beyond that distance his influence could only be transmitted either by his personal migration with respect to his neighbors or by the migration of his auditors and their repetition of his ideas from memory. Gradually, after writing became a familiar mental habit, written words superseded repeated speech, and document, tradition. Writing thus vastly increased the effective sphere of psychological influence, although the diffusivity of the new method must have been but small. Engineering steadily enlarged the sphere of influence by developing the press, the railroad, and the steamship, by which the written word could be reduplicated and carried faster and farther. The old semaphore telegraph from hill to hill, still found in various parts of Europe in sequestered desuetude, went a step further and added speed to the travel of thought; but the electric telegraph and telephone have enormously increased the range of mental influence. Even now the fetters of thought are closing upon the arms of the ocean, and wireless telegraphy promises in time to extend the transfer of ideas to the uttermost distances of the sea. The effect is multifold. The tendency is always for the best intelligence to have its influence most widely distributed, considering the best as that which the community esteems best at the time; so that the extension of the range of mental influence always tends for the benefit of the many and the selection of the fittest. The consciousness of the individual being able to influence his neighbors at any distance on the planet gives him greater confidence in the success of undertakings dependent for their effect upon widespread coöperation. The consciousness of the individual that he is always within the sphere of influence of his leader exerts a great psychological supporting influence in times of difficulty and doubt. It is equivalent to a bridging over of the distance between the strong and the weak. Any one who has ever received from land a telegram when far out at sea, either by wireless telegraphy, or by a lifted submarine cable, will testify to the intensity of this psychological influence.

According to the census returns of 1902 the number of telegrams forwarded commercially during that year in the United States was 91,650,000; or 1.2 telegrams per annum per head of population, at an average cost per message of 31.8 cents. In the same year the number of reported telephonic conversations in the United States was nearly 4950 millions, or 65 per head of population, at an average cost per conversation of 1.65 cents.

Along with the swift and extended radius of thought that electrical engineering offers, by the mutual relations of immaterial mentality and the immaterial ether, there is also necessarily involved a reduction of psychological restraint and an extension of psychological freedom. A part at least of the discomfort of human beings often arises from a disconformity between their modes of thought and of their mental relations to those of the individuals surrounding them. Occasionally an individual who is psychologically ill-adjusted to his environment, and who is therefore ineffective in his coöperation with it, may subsequently become more usefully effective in response to a changed mental environment. The greater and swifter the radius of thought activity under the influence of engineering methods, the greater the stimulation to migration that leads from a lesser to a greater harmony of adjustment between the internal and external mental activities of the individual, to the increase of general comfort and well-being. The segregation of associable mental activities is simplified and rendered frictionless by whatever extends the rate and range of ideas.

In its moral effect upon the community at large, electrical engineering must have the same effect as all other branches of engineering; namely, to dispel illusion, dignify all labor, exalt truth and precision, gradually eliminate superstition, bring home to consciousness the infinite simplicity of nature, and indicate that no good thing can be humanly acquired without effort and training.

In a certain sense engineering is destined to assist in effecting the apotheosis of humanity. Every step taken by the people along the path of civilization makes degeneration to dissociative barbarism the more difficult and unlikely. The methods that men adopt to subject the immediate universe to their will react by subjecting their will to the laws of the universe. Centuries ago men dreamed of the civilization that they, by uniting and coöperating, might initiate for their successors to attain. Already that civilization has so far dawned that it has modified us to its requirements, and we live for it as well by it. The difficulty of fitting ourselves for it is greater than that of fitting it for us. Whatever modifications civilization may undergo in the course of time must be molded in accordance with the developments of engineering, which are themselves but the interpretations into human ideals of the attributes of nature.

ELECTRICAL ENGINEERING PROBLEMS OF THE PRESENT TIME

BY MICHAEL IDVORSKY PUPIN

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ENGINEERING problems differ from crude scientific problems by the definiteness of their aim. They are created by the industrial development of the country, and their solution forms the next step in the progress of this development. The problems in pure science do not have this intimate connection with the present state of the technical arts; they affect it in so far only as their solution contributes additional means for the solution of the existing engineering problems and leads gradually to the formulation of new ones. Public demand is the driving force which impels the engineer in his study of any given problem; the loosest kind of a coupling connects the work of the crude scientist with public demand. This does not mean, of course, the existence of any public indifference in this respect. The intelligent public watches with keen interest the steady progress of pure science; partly on account of the intellectual pleasure which one derives from the contemplation of the beautiful mechanism which purely scientific research reveals in the background of various physical phenomena, but principally on account of the recognized fact that the progress of pure science leads to the formulation of new engineering problems, the solution of which is essential to our immediate social progress, our moral and material development. The intelligent public knows with a certainty amounting to mathematical accuracy when the time is ripe for the formulation of new engineering problems, and it is ready then to lend its strong support to the engineer who offers a solution. When Bell discovered a method of obtaining an electrical facsimile of articulate speech, and constructed the first telephone which represented an embodiment of his great discovery, the intelligent public understood readily that the time was ripe for the formulation of a new engineering problem, the problem of transmission of speech over long distances. It was ready then to contribute cheerfully its share to the sacrifices which had to be offered, in order to obtain a satisfactory solution of this great engineering problem. It is, indeed, not a mere accident that the most intelligent state of this union, the state of Massachusetts, contributed far more than any other state to the sacrifices which had to be offered, in order to develop Bell's remarkable discovery and invention into the greatest civilizing agent of modern times.

These are the considerations which guided me in answering the question: Which of the many electrical problems of to-day should be considered as the "Electrical Engineering Problems of the Present Time"? Evidently those electrical problems must be selected the solution of which, in the opinion of all competent judges, represent the next step in the evolutionary progress of the existing electrical industries. Vague and indefinite propositions, such as, for instance, the direct transformation of the chemical energy of burning coal into electrical energy, the generation of cold light by electrical processes, and so forth and so on *ad infinitum*, must be excluded from this discussion. They are not in any sense of the word electrical engineering problems. The problems discussed here relate to the extension of the existing methods, which have been sanctioned by long practice, in electrical traction, electric lighting, telephony, wireless transmission, and ordinary telegraphy.

The Electrical Traction Problem

Electrical traction has been developing steadily during the last twenty-five years and has covered the field well which was originally mapped out for it, namely, the transportation of light traffic over comparatively short distances. Within these limits it has done its work admirably, surpassing even the most sanguine expectations of its original promoters. These results encourage the public and the engineer in the belief that the time is ripe for the formulation of the new electrical traction problem and for its satisfactory solution.

The new electrical traction problem is the problem of substitution of electric power in place of the steam locomotive on trunk lines; it is the problem of heavy electrical traction over long distances. The problem can be more clearly stated by referring to a specific case. Let us suppose that the Pennsylvania Railroad Company has decided to consider the advisability of equipping its lines between New York and Philadelphia with electric power, and that with this end in view it has obtained a sufficiently large number of reports from competent electrical traction experts. Every one of these reports would contain a careful examination of the problem under discussion, that is, the problem of heavy electrical traction over a distance of one hundred miles which, in the present state of the art of heavy electrical traction, is certainly a long distance. It is highly probable that no two out of a large number of these reports would agree even approximately in all the details involved in the problem, because there is no doubt that there are a considerable number of pet schemes in heavy electrical traction, each one of which has its ardent admirers and stanch champions. Nevertheless it is fairly certain that they would all agree on the vital questions involved in the problem. These questions are: First, can the existing methods of electrical power distribution over a distance of a hundred miles take care of heavy traction? Second, would substantial administrative advantages, capable of increasing the capacity of the existing tracks, result from the substitution of electrical power for the steam locomotive? Third, could the continuity of service be sufficiently well secured?

The answer to the first question would undoubtedly be in the affirmative in every one of these reports. The powerful electrical locomotive recently constructed by the General Electric Company for the New York Central Railroad and the experimental results obtained with it leave no room for any reasonable doubt that electrical traction machines can be built, which will take care of any practicable load and at any practicable speed. The Westinghouse Electrical Manufacturing Company of Pittsburg is completing for the Swedish Government a heavy traction electrical locomotive, which is considered by some to be even an advance upon the electrical locomotive of the General Electric Company just referred to.

The answer to the second question would also be decidedly in the affirmative in every one of these reports. Very substantial advantages would certainly arise from the substitution of the electrical motor for the steam locomotive. Our entire experience with electrical traction so far justifies this belief, and these advantages are so numerous and so self-evident, that a specific discussion of every one of them would be entirely beyond the scope of this paper, and would, besides, be entirely superfluous. Suffice it to state here briefly the two chief advantages which would arise. They are, first, the possibility of running smaller trains at much more frequent intervals; secondly, higher speeds with greater safety could be obtained. This means a very substantial saving of time and the resulting great increase in the transportation capacity of the existing tracks.

In the popular mind the substitution of electrical power for the steam locomotive seems to convey the idea that the chief object of this substitution is the saving of power; but nothing is as far from the actual point at issue as a view of this kind. The coal-bill is a small item in the operating expenses of a road, and cuts no figure in the study of the problem before us. The cost of the equipment is a different matter; it does cut a very important figure in the operating expenses of the road, and it seems to be admitted on all sides that the cost of the electrical traction equipment would be considerably higher than that which accompanies the employment of the steam locomotive. But the increased transportation capacity of the tracks and the increased safety of transportation would and should more than balance this increase in the cost of equipment.

The third question is: Can the continuity of service be sufficiently well secured with the prevailing methods of electrical traction? To find a complete and satisfactory answer to this question is the most difficult part of the problem.

With the present method of steam locomotive traction every train with its locomotive is an independent unit, so that an accidental derangement of any one of the units does not interfere very seriously with the operation of the rest of the road. A blizzard or a flood may, to be sure, cause a suspension of operations on the whole road, but nothing short of this inimical action of the elements is capable of producing this result. In electrical traction, on the other hand, the various units on the road are all interconnected through the conducting wires which connect them with the power stations. Any accident which suspends the operativeness of a power station will bring to a standstill the whole traffic on the section which is fed by that particular station. This difficulty, however, exists also in the electrical distribution of power for lighting purposes in large towns, and past experience shows that the present methods of electrical central station construction and management make the risks of discontinuity in the service on this score extremely small. It must be remembered, however, that distribution of power for lighting purposes in large towns employs underground conductors, which is one of the most effective means of protecting the continuity of service against the hostile action of seasons and elements. In heavy electrical traction, underground conductors are out of question for reasons which are so evident that they need no further discussion. This introduces one of the most serious difficulties into our problem.

The third-rail method limits the practicable electrical pressure at which the electrical energy is conveyed into the train; besides, it introduces the very serious difficulty of maintaining a sufficiently good electrical contact during the winter season when the ground is covered with ice and snow, not to mention several other difficulties which, it is generally admitted, render the third-rail method entirely inadequate to heavy electrical traction. The overhead trolley seems, in the opinion of the majority of competent engineers, the only permissible method of conveying electrical energy from the central station to the train. At any rate, this is the meaning conveyed to my mind by the fact that the New York, New Haven and Hartford Railroad Company has asked permission of the legislature to abolish the third rail and substitute in its place the overhead trolley. But if the overhead trolley method is to be adopted, then the smaller the number of wires employed to convey the electrical energy to the train, the better. This seems to me to be the real meaning of the extreme anxiety on the part of the electrical engineer to design an asynchronous single-phase alternating-current motor capable of developing large power. The results obtained in this direction during the last few years are encouraging, and they seem to have brought us very near to the solution of the heavy electrical traction problem. Summing up the considerations discussed above, it seems that the composite judgment of the best technical opinions can be stated somewhat as follows: Convey the electrical energy from the station to the electrical locomotive by means of a single-phase alternating current at high tension, say, 20,000 volts, employing, of course, a single trolley-wire. Let the locomotive serve as a sub-station in which the high-tension current is transformed down to a suitably low tension, and employ either induction motors or direct-current motors to convert the low-tension electrical power into mechanical propulsion.

The possibility of employing single-phase alternating currents contributes very materially to the possibility of securing continuity of service in heavy electrical traction by reducing the multiplicity of contacts to a minimum; theoretically, one contact for each locomotive. But that single contact must be rendered as secure as mechanical art can make it. The trolley-wire hanging with a convex curvature toward the track and supported on wooden poles such as we see on ordinary trolley-roads would never do. In place of the flimsy structures we must have well-anchored steel towers supporting messenger-wires of steel hanging in catenary suspension, and to these the conducting trolley-wires are neatly and securely attached so as to be at all of their points parallel to the track. The whole structure when finished looks like an endless suspension bridge, the steel towers being the piers of the bridge. The messenger-wire represents the gracefully curved span between the piers, and the trolley-wire is the platform over which the traffic of the bridge is maintained. Such trolley-lines have actually been constructed and operated not only out West and in some parts of Europe, as for instance on the famous Berlin-Zossen section, but also on the Long Island Railroad, where electrical traction on a somewhat larger scale is contemplated in the very near future. Structures of this kind are extremely solid and quite capable of defying the most stubborn attacks of the elements, but they are, of course, expensive, and the question arises whether a trunk line, say, between New York City and Philadelphia, equipped for heavy electrical traction in accordance with the most approved methods, so as to secure a rapid transportation of even the heaviest loads in large units as well as in small units at frequent intervals and with perfect security of the continuity of service, — it is a question, I say, whether such a solution of the problem before us is a financially attractive proposition.

There is a strong belief among the progressive members of the engineering profession that the question will be answered in the affirmative in the very near future.

The Electric Lighting Problem

The efficiency of the electrical arc-lamp is satisfactory; its mechanism is somewhat complex, and the sharp shadows produced by a powerful source of light concentrated in a very small volume are objectionable, not to mention the physiological effect upon the eyes of an intense source of this kind. On the whole, however, this form of electric lighting is considered as highly efficient and effective although not quite so cheap as some of the modern chemical methods of light-generation. Electric lighting by incandescent filaments is the field in which the public is awaiting marked improvements. This is the form in which lighting by electricity is distributed in small units. It is ideal in its simplicity and convenience, but it is a luxury in which the rich, only, can indulge; it is too expensive. The so-called fine arts are aristocratic; science and the technical arts are nothing if not democratic. The fruits of their labor must be within reach of everybody; if not, the soil which bears any particular one of these fruits will not be sufficiently cultivated by the public and it will soon become a hothouse product of the rich or cease altogether. To transform incandescent electric lighting into a democratic institution is one of the electrical engineering problems of to-day. Its solution involved many problems in the economy of generation and distribution of electric power, all of which have been satisfactorily solved by the electrical engineer, so that the main solution has converged finally to the following proposition: To find a substance which will have a sufficiently high resistance, will stand a higher temperature than the carbon filament without too rapid deterioration, and the radiation of which at this high temperature will be rich in visible waves. Osmium, tantalum, and some other refractive rare metals have been tried and seem to promise well. But in many respects the most satisfactory results have been obtained by Peter Cooper Hewitt with his mercury vapor lamp. The efficiency of this form of electric lighting, both in large and in small units, is remarkably high, over four times as high as that by ordinary incandescent lighting, and the simplicity of the apparatus is ideal. In addition to its high efficiency the mercury vapor lamp has the great advantage over all other forms of electric lamps in the fact that its light proceeds from a source which is distributed over a large area. This prevents the formation of sharp shadows, a great desideratum in workshops, where it is important that the workman should be able to see all around the object which he is handling. For this reason the lamp is making a rapid headway into factories, draughting-rooms, libraries, and laboratories. Its poverty in red rays will keep it temporarily out of the drawing-room and other places where the complexion of things and of people must be shown off at all cost. This, however, seems to be the only defect of this new form of electric lighting and it is sincerely hoped that this defect will soon be remedied.

The Telephonic Problem

The engineer has to determine how much time, money, and personal convenience the average subscriber is willing to sacrifice, in order to communicate with another subscriber in some other place, and then provide a satisfactory service which will return some profit to the operating company or to the state. The proposition is extremely complex, particularly in this country where unexpected legislative action introduces so many unknown quantities into the calculation of the engineer. Every now and then the legislator takes it into his head that he knows more about the science and art of telephone engineering than anybody else, and then, with a bold stroke of his pen, he cancels the final figures of the engineer, the permissible charge, and substitutes his own, looks wise, and leaves the engineer to lament the loss of the fruits of his laborious calculations and to wish that he lived in autocratic Russia where the telephone system belongs to the Czar and no conceited legislator is allowed to interfere with a business of which he has not even the faintest shadow of anything approaching the semblance of an idea. Thanks, however, to the superior intelligence of the engineers of the American Telephone and Telegraph Company and to their extraordinary courage, telephonic art is progressing very favorably in spite of the arrogant legislator and the wicked demagogue, and of the most annoying and heartbreaking difficulties which they are placing, at almost every step of progress, in the way of the patient and intelligent worker in the telephonic field. The American telephone engineer must reckon with an unknown and unknowable quantity, — the legislator. The only satisfactory way to handle this quantity is to ignore it and to adjust the other elements of telephonic problems in such a way that the result will, in all probability, come out right no matter in what direction the legislative cat may decide to jump.

The European engineer is much more fortunate in this respect. The telephone system belongs to the government. The charge is fixed, and if it brings a profit to the state, well and good; if it does not, the taxpayer makes it right. If some taxpayer kicks because he has to pay for somebody else's telephoning, he is told that the existence of the telephone system is of general benefit to the state. It develops commerce and industry and this improves the moral and material condition of all, both of those who telephone and of those who do not telephone. This sounds like good philosophy, and shifts the burden of the argument upon the taxpayer who, for self-evident reasons, generally prefers to argue no further. The permissible charge is, therefore, eliminated from the engineering problems of telephony, in Europe, because it is a fixed quantity; in America, because it depends upon an unknowable quantity, the legislator and the demagogue, the last one often in form of some sensational newspaper which spares no pains to persuade its readers that the telephone industry in this country is the same kind of an institution as the beef trust, the coal trust, the gas trust, etc., etc.

If there is any technical advance of which this country ought to be proud, it is indeed the art of telephony. In no other branch of engineering or technology has this country maintained its lead as easily as in this, so much so that there is no second, although there is no other kind of engineering which is as highly scientific and technical as telephone engineering; and yet the demagogue paints it in the colors of a beef trust, a coal trust, or some other social aberration of this degenerate age.

Two more essential quantities are left which the telephone engineer weighs in determining the solution of the telephonic problems; these are, — first, the maximum amount of time; secondly, — the maximum amount of personal convenience which the subscriber will sacrifice in order to communicate with another subscriber. The better the service the more will the subscriber sacrifice for it, but at best he is not willing to give up much, and so the final problem of the telephone engineer reduces itself to this:

To provide a first-class service, which will be at all hours and under all conditions of weather at the subscriber's disposal, at a moment's notice and anywhere and with anybody. This problem has been solved in this country and in Germany, as far as local service is concerned, and the great problem in telephone engineering to-day is to do the same thing for the interurban telephonic communication. For example, a telephone subscriber in New York should be able to call up any other telephone subscriber in New York, Boston, Philadelphia, Baltimore, Washington, Wilmington, Trenton, Newark, Paterson, New Haven, Hartford, Providence, or any other populated centre within a radius of about two hundred and fifty miles of New York City, and get just as quick and just as good service as he gets with any subscriber in his own town. The solution of this problem would mean that all these populated centres within a radius of two hundred and fifty miles, covering a territory of a large empire, would form, telephonically, one town, where within a time interval of a few minutes one could call up anybody that is of any account and have a pleasant chat or any other kind of a conversation. A few years ago the solution of this problem would have been impossible, to-day it is, and the engineers of the American Telephone and Telegraph Company are actually working upon it with all the vigor of their young and well-trained intelligence. A similar problem occupies the attention of the engineers of the Siemens and Halske Company of Berlin.

The new method of high potential transmission of electrical waves by conductors of suitably increased inductance has given them a new weapon for attacking the problem, and they are wielding it with extraordinary force and skill. The telephonic union of the thickly populated centres just mentioned into one community covering the area of a large empire means, of course, the stretching of thousands of wires between such towns as New York, Boston, Philadelphia, Baltimore, and Washington, and that means the employment of cables in underground conduits. No pole line could support anything like that multiplicity of wires. Transmission over underground cables over such distances was an impossibility a few years ago, when a distance of twenty miles was considered quite a serious matter. To-day there is a high-tension telephonic transmission cable containing a large number of wires supplying a most satisfactory telephonic transmission between Boston and Worcester, Massachusetts, a distance of over forty miles, and the experimental results obtained with this cable by connecting several circuits in series back and forth between Boston and Worcester justify the confidence of the engineers of the American Telephone and Telegraph Company that they will certainly solve, in the near future, the grand problem of the telephonic union of the great centres of the Atlantic coast. The same confidence is expressed by the engineers of the Siemens and Halske Company of Berlin in their work on the problem of telephonic communication between Berlin and London through a cable over 400 miles under the North Sea.

A side issue of this problem is the problem of establishing a satisfactory telephonic communication between any two important centres of a continent. The new principle of high-tension telephonic transmission, mentioned above, affords a satisfactory solution, provided, however, that the insulation of overhead wires can be maintained above a certain low limit. Investigations in this direction conducted by engineers of the American Telegraph and Telephone Company, and by the engineers of Siemens and Halske of Berlin, have yielded most satisfactory results, so that the question whether we shall soon have telephonic communication with San Francisco and other places on the Pacific slope, or between say St. Petersburg and Madrid, is merely a question of a sufficiently strong commercial demand.

The Wireless Wave Transmission Problem

The public is not yet on terms of familiarity with the wireless transmission scheme. The public is not quite sure that it knows who is the real representative of this new civilizing agent. Is it Marconi? Is it Tesla, or is it some one of the many other dark luminaries? Marconi used to be their wireless hero, but there have sprung up lately so many champions of the cause of other inventors — and the courts have not spoken yet — that the public is somewhat puzzled. Under these conditions of uncertainty the public is not quite sure that the time has yet arrived to decide whether wireless transmission is essential to its present happiness. Besides, the gods of the Army and Navy departments have decided that wireless telegraphy is an essential element of their military equipment and the public must step back. The public can no more be allowed a free play with wireless telegraphy than they can be allowed to keep dynamite in their back yards or to steam about in torpedo boats. The war lords have spoken, and neither the inventor, nor the disappointed stockholder, nor the patent office dare open their mouths. When a United States general or admiral announces with all official solemnity that the scientists of the Army or Navy have devised a wireless method of their own and the intelligent public observes that not only this military wireless system but also that other alleged new wireless systems, recognized and patronized by the Government, and known as the Fessenden, De Forest, Slaby-Arco, Braun, and I do not know what other kind of systems, look in every particular like the familiar old Marconi system, they stand perplexed and ask, — well, who has invented what? For they must either all of them have invented the same thing and do not know the remarkable coincidence, or nobody has invented anything, or one man is the real inventor and the rest are bold-faced fakirs. Each one of these hypotheses seems equally improbable. This mixed-up state of affairs has produced a marked depression of public interest in wireless telegraphy, and consequently it has delayed quite seriously the progress of this beautiful new technical art. But fortunately for the art, it is so attractive that in spite of its associations with many apparently disreputable characters it is still cultivated by serious men of true scientific spirit and devotion. These men know quite well that there is one wireless scheme only, that it is a clean-cut invention of the first order, and being such it is fairly certain that it belongs to one man only, the decrees of the Army and Navy scienticulists notwithstanding; and they also know that it devolves upon them and upon the original inventor, and not upon the scienticulists of the Army and Navy, to solve the present problem of wireless telegraphy, which they feel confident to be a true engineering problem, because its solution is quite within reach of the present state of the electrical art. This problem is: A rapid, reliable, and selective communication between the continents and any point on the Atlantic. A ship on the ocean should always be in electrical touch with land.

That which is needed is an oscillator, sufficiently powerful and persistent to produce strong resonance effects. A wave-train consisting of say thirty complete waves is for all practical purposes as effective in producing strong resonance effects as a continuous train.

In wireless telegraphy oscillators of a frequency of about one million oscillations per second are commonly used. To give a wave train of thirty complete waves the oscillator would have to maintain its vibrations during an interval of approximately one thirty thousandth of a second. An oscillator of this frequency and possessing a condenser of .1 microfarad charged up to 50 thousand volts would during that brief interval of time radiate energy at the rate of approximately 15 thousand horse-power. Assuming that the giant Marconi radiator has an area of 1000 square yards, there would proceed from every square yard during a time-interval of one thirty thousandth of a second radiant energy at the rate of 15 horse-power. The radiant energy sent forth into space by every square yard of the bright surface of the moon, assuming even that it reflects all the sunlight which falls upon it, is sent out at the rate which is less, considerably, than one horse-power. Yet, although its distance from us is so enormous, our eye can feel its radiant energy even some time before the full moon has risen above the horizon and we can measure the relative amount of its radiation, sent to us, by electrical receivers which do not differ essentially from some forms of receivers employed in wireless telegraphy. This simple comparison shows what an intense source of intermittent radiation a Marconi radiator can be when actuated by a sufficiently powerful oscillator. A generator of 15 horse-power would be quite sufficient to charge such an oscillator a hundred times per second, which is sufficient even for the most rapid kind of ordinary telegraphy in actual practical use anywhere. Such an oscillator operating, say at Cape Cod, would very probably be felt at every point of the Atlantic between the European and the American coast, particularly on receiving circuits which are in resonance with the oscillator. Such an oscillator has not yet been constructed and it may not appear quite clear how so much electrostatic capacity can be crowded into an oscillator of the enormous frequency employed in wireless telegraphy. Yet I feel fairly confident that the present state of the electrical science offers abundant means for doing the thing in a very simple manner and that it will be done in the near future. But I am afraid that when it is done the official back of the electrical cat upon which the military and naval scienticulists rely for their charging generator will curve up in mad disorder; there will be an interruption in the very important official wireless communications between naval stations, one requesting the other for a loan of a few yards of rubber hose. A session of the war council would probably be called to decide how this intolerable interruption of official business can be avoided, and after careful consultation with the military scienticulists the war lords would probably decree that the existence of such thundering machines on the seacoasts is a public nuisance because it interferes with the wireless business as conducted by the scienticulists of the Army and Navy and required by the conditions existing in their administration. The wireless problem cannot become a true engineering problem so long as the war office interferes with a technical art of which it has no intelligent grasp. Soldier, stick to your guns; leave wireless telegraphy to people who can handle it with more intelligent grace and skill.

The Telegraph Problem

It is the most difficult electrical engineering problem before us. What is wanted is a system which will perform a large part of the work of the ordinary mail at any rate between thickly populated centres. That means very rapid, efficient, and accurate automatic machine sending and receiving. It also means multiplexing way beyond the performance of the present quaduplex. Theoretically the solution of the problem looks easily possible and actual experimental demonstrations have been given to prove the correctness of the inference drawn from pure theory. Mr. Patrick Delany's work in this particular direction should be honorably mentioned here. But very serious practical difficulties exist, which are known to those only who have been for a long time in actual touch with the telegraph business of this country. This business has developed historically; each epoch in its development marks an epoch in the development of the general business methods which prevail in this country.

In European countries, the telegraph belongs to the Government and its development was influenced very much by the requirements of the war office. Private business had to accommodate itself to the telegraphic conditions created by these requirements.

To illustrate: Many of the trunk lines in this country are leased to private individuals, bankers, brokers, etc. The telegraphic companies do their own business over these leased lines, employing the quadruplex method. In fact not only the telegraph company, but several subscribers are working over the same trunk line simultaneously, each one, except the telegraph company, ignorant of the fact that the other fellows are using the same ethereal channel of communication. This practice is practically unknown in Europe.

It is the opinion of men of recognized ability, who have grown old in the development and management of the telegraph business in this country, that the numerous long-distance lines covering the vast territory of the United States are so costly, both from the standpoint of initial expense for construction, and also from the standpoint of subsequent expense for maintenance, that they would hardly pay if it were not for the rental of these lines to private individuals. The same statement holds good for the transmission of intelligence over long-distance telephone wires. These, too, are rented in very many cases to private individuals for telegraphic purposes, so that long-distance telegraphy and telephony are often carried on simultaneously over the same wires.

Any new improvement which would bring us nearer to the solution of the general telegraphic problem is impracticable if it interferes seriously with the existing conditions under which, according to the preceding rough sketch, telegraphic business is conducted here at present. This explains the well-known fact that several American inventions in telegraphy were adopted abroad and proved themselves valuable, although they failed to find recognition at home on account of their inability to satisfy the requirements of the telegraphic situation existing here. The disappointed inventor can hardly be blamed for feeling sore over the apparent lack of appreciation in his own country. But if he could be prevailed upon to raise himself to a loftier level of objectivity, and thus obtain a broader view of the telegraphic situation at home, he would certainly be less severe in his criticism of what he considers to be the hide-bound methods of the antediluvian telegraphic monopolies which, in his opinion, smother every intellectual activity of inventive genius.

Those who are most familiar with the mathematical theory of transmission of rapid electrical impulses for telegraphic purposes seem to agree fairly well on one point at least; it is this: The alternating current is the most suitable form of electrical transmission for telegraphic purposes. The solution of the general telegraphic problem by means of automatic transmission, and by the adoption of multiplex methods with all the possible refinements of which these methods are capable, cannot be reached unless the alternating-current method of transmission is adopted. But then we should have in telegraphy the same practical difficulties which telephone engineers met in the early days of telephony. These difficulties are summed up by the telephone engineer and condensed into a single word, — cross-talk. It means conveyance of electric energy from one wire to another by electrostatic as well as by electromagnetic induction. It is the more powerful the higher the frequency of the alternating current employed in the transmission. The telephone engineer overcame this difficulty gradually by giving up the employment of the earth as the common return conductor for all his transmission wires, and from that day dates the symmetrical conducting loop of the metallic return circuit. Having adopted this expediency it was then a comparatively easy matter to avoid cross-talk, due to induction, by a suitable transposition of the neighboring circuits with respect to each other.

The introduction of the alternating current into telegraphic transmission would compel the telegraph engineer to resort to this same expediency which was long ago adopted by the telephone engineer, otherwise he would expose himself to the serious difficulties arising from cross-signaling.

Considering the fact that practically all telegraph lines in the country employ the ground return, it is clear that the general introduction of the alternating current into telegraph work would involve practically a reconstruction of a large part of the vast network of telegraph wires in the United States. I do not know of a single telegraph engineer in this country who would have the courage to assume the responsibility of advocating before his board of directors a policy of this kind. And so, as far as this country at least is concerned, the solution of the general telegraphic problem seems to be a matter of the dim and distant future.

SECTION D—MINING ENGINEERING

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(*Hall* 11, *September* 24, 10 *a. m.*)

Chairman: Mr. John Hays Hammond, New York City.
Speakers: Professor Robert H. Richards, Massachusetts Institute of Technology.
Professor Samuel B. Christy, University of California.
Secretary: Dr. Joseph Struthers, New York City.

THE RELATION OF MINING ENGINEERING TO OTHER FIELDS

BY ROBERT HALLOWELL RICHARDS

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The two papers of this Section appear to call for discussions more or less educational in their intent. The first paper to draw the picture of the various calls the mine makes upon its officers, leading up through the development of the business and finally reaching as a climax the educational requirements to fit the man for the place, deals more particularly with the man. The second, to review the past development, draw the picture of the present, and indicate the lines of progress that are most needed in the near future, deals more particularly with things.

I will begin my story by attempting to show how universally the work of the mining engineer reaches the interests of all. I will then trace from early beginnings the development from the primitive chance find of attractive mineral specimens to the modern, fully equipped mine. I will show how the mine not only supplies wants of all classes but calls upon many lines to respond by contributing to mine development. And, finally, will indicate the educational lines which are developed to bring men to as good an understanding as possible of how to get the most effective results in mining with the least expenditure of material and effort.

The province of the mining engineer may be defined as comprising all the duties and abilities that a mining engineer may be called upon to perform or possess, the end point of which is the extraction of valuable minerals and placing them on the market for the service of man. He brings from the ground into active use values which previously lay dormant and unknown to the uninitiated. He builds, out of apparent nothingness, things which eventually make for use and beauty in the service of men. He has, therefore, wide ethical and philosophical relations with the development of the human race.

Development of the Mining Engineer

Looking back through the eye of the imagination to prehistoric times, we may form a conception of an order of advance in things mining. The primitive man picked up colored stones, bored holes in them, and wore them as amulets for decorative, religious, or medicinal reasons. He found the precious stones and prized them for their decorative effect. He found the gold in nuggets, and later, that he could polish, flatten, and shape it, and made a beginning in the metal manufacturing art.

Gold and precious stones at a very early date must have risen in value and begun to be property, and also begun a career as a medium of exchange. A complete mining plant, at this time, may have been an area of land with ore specimens scattered on the surface of the ground and buried in the surface soil, with a few men digging with pointed sticks and moving the soil with rude wooden shovels. The existence of ownership in the soil and mineral may have developed later.

Stimulated by mineral discoveries, the miner made efforts to define, identify, and name his mineral species and so gave a beginning to the science of mineralogy; and his efforts to establish rules of occurrence of his valuable minerals did the same for geology.

The primitive Asiatic at an early date found the effect of fire on minerals and picked up lead, copper, or iron in the ashes of his camp-fires. Cornwall tin was found in the same way.

The primitive metallurgist then experimented with his fires and got silver by burning up his lead, and bronze by alloying copper and tin.

The possibilities fascinated him, the getting stimulated the desire to get, and the ingenuity to fashion the tools to get with. In fact, the metallurgist has done much to stimulate the development of the chemist. There came to be a systematic use of fires for roasting ore, reverberatories for desulphurizing ore, crucibles for melting, cupels for purifying silver, hearths and shaft-furnaces for smelting.

The miner, pushed by his metallurgical partner, soon got to the end of the loose ore lying on the surface and began breaking it from the ledges with his stone hammers. He found that by heating the ore and quenching it with water it would crumble more easily. In fact, this was probably the chief method of mining for many centuries.

A mine at this period may have been a pit or trench twenty feet deep, more or less, from which the ore and water were carried out on men's backs, using a tree with stubs of branches for a ladder.

In time the metallurgist found that by manipulating his iron in connection with carbon he could harden it and that the hardness was greatly augmented by quenching it in water. He had made the discovery of steel and of tempering.

The miner asked for a better hammer and got one of steel and with it the "point" which by blows of the hammer chips and severs the ore from the ledge. The hammer and point, "Schlegel und Eisen," must have been the standard mining tools for many centuries.

The primitive American mined copper at least 500 years before the discovery of this country by Europeans (Egleston). This is indicated by counting the rings in tree-trunks growing in their old workings. They mined the copper with stone hammers, heating the rock with fire to make it more friable. They mined to a depth of twenty or thirty feet, but rarely went underground; used wooden shovels to move the rock and wooden bowls and bark troughs to dispose of the water. They did not want and could not use pieces of copper larger than a few pounds, which they took as they found them, beat out cold into shapes, leaving the silver attached to the copper. They apparently had no knowledge of concentration or of smelting. They used the copper for tools of the household, of the shop, of the chase, and of war, as well as for decorative purposes.

The making of iron tools enabled the miner to penetrate into the ground. He devised ropes, buckets, and a rude windlass for lifting out ore and water. His roof and walls of rock began to fall in on him and it was necessary to bring in timber props and to leave pillars of ore to hold the walls apart.

About this time the horse-windlass and a better quality of rope must have been designed for hoisting from greater depths. Mines at this time may have reached a depth of hundreds of feet with tunnels and galleries though small in size, yet cut out with a care and finish almost like that of the stonemason's work on public buildings. Such tunnels of three hundred years ago can be seen to-day in the German mines.

The metallurgist asked for cleaner ore, free from earthy and siliceous impurities which hindered or prevented his smelting operations; to effect this, the crude stamp for crushing, and the sweeping buddle for concentrating ores were developed.

As to the periods when the mineralogist, the geologist, and the chemist became separate professions, investigating everything in their lines and contributing from their stores of knowledge to the benefit of the miner, I will not discuss. But the time has never yet been reached when the miner could afford not to have a good working knowledge of those subjects.

The next great step was the use of drill and blasting powder (A. D. 1620). The slow, tedious chipping was replaced by the more rapid boring and blasting out of rock masses, and the speed of mining increased immensely.

A. D. 1776, the steam engine came to the help of the miner. The pumping engine came first, for removing water, and then the hoisting engine.

About A. D. 1840 the locomotive was invented and used for hauling coal and ore.

We sometimes think of all engineering depending on or pertaining to the steam engine, whereas the true engineer is a man who must adapt means to ends, whatever they may be and whether he ever did or did not know of them before. He can use precedent as far as it will go, and must fill in the rest from his brain. He may have to harness up a waterfall on the side of a mountain, bring down the water in a great pipe, and level gravel hills with a water jet more powerful than those used by our city fire departments. Or he may have to use the water to compress air and convey it in pipes to his mine and use it there to drive his powerful hoisting and pumping machinery and his power drills for drilling the rock.

In 1860 nitro-glycerine was introduced as a powerful blasting material, adding to the speed and economy of the work of excavation.

The miner, by his needs of prime movers, transmitting machinery, transporting machinery, and use of water, has contributed much to the development of the mechanical engineer and to a less degree to the railroad and hydraulic engineer.

The miner and the agriculturist really take shares in this development. They are both fundamental callings, taking the good things from the ground. The farmer has probably helped more in the development of the railroad, while the miner's field has given him a greater hand in developing power machinery and hydraulics.

Later these all became independent professions, and having made great advances in their studies they now in their turn contribute advanced ideas to the benefit of the miner.

But here again no mining engineer can afford to be without a good working knowledge of mechanical engineering, constructive engineering, hydraulic engineering, or railroad engineering.

This brings us to the great mines of to-day, and if we draw a few illustrations from the Calumet and Hecla Mine of Lake Superior, it will, perhaps, serve as well as any.

This represents both the primitive and the most modern things in mining. It was discovered by a prehistoric pit evidently worked by a race of advanced intelligence before the Europeans reached this country and it is now equipped with the finest mining machinery in the world. This mine is opened up by some fifteen shafts, more or less, on the slope of the deposit which are about 400 feet apart. The longest shaft is opened about 8000 feet down the slope. A vertical shaft nearly a mile deep connects with this below. Every one hundred feet, going down, there is a level or horizontal tunnel driven along the deposit either way, and these 100 by 400 feet blocks of copper-bearing rock are worked out by drilling and blasting with dynamite. The roof is temporarily supported by carefully designed timbering which holds up the roof until the rock is all worked out, and then gradually crushes, letting the roof fall in. Every one of the levels has been carefully surveyed so they will properly connect with each other and the ends will not go beyond the boundary-lines, and they are supplied with a railroad track and cars. Every shaft has been surveyed, supplied with a track for the hoisting-skip and a hoisting-rope, at the top of the shaft is a rock house with two immense rock breakers, two great sheaves for turning the hoisting rope and a hoisting engine powerful enough to lift at great speed the rope skip and copper rock, weighing many tons, to the surface. Beneath the breakers is a great rock bin and tracks for shipping the rock down to the mills at Lake Linden, five miles away.

Several great air compressors furnish air for the rock drills operated by 3000 miners, more or less, producing 5000 tons or more of copper rock per day.

The mine has waterworks bringing the pure water of Lake Superior up to 600 feet in height, four miles in distance, to supply the boilers and also the company's houses.

A huge revolving fan uses one shaft for ventilating the many miles of shafts, levels, and stopes, giving the miners fresh air and removing the powder smoke.

The mine has machine-shop, foundry, blacksmith-shop, and carpenter-shop, capable of doing the finest work on large or small scale.

Going to the mills at the Lake, we find two large mills with about eleven steam stamps each, 22 in all. Each of these stamps can crush nearly 300 tons of copper rock per day and each has a large number of jigs, Wilfley tables, and revolving tables for concentrating the crushed rock. They appear like monster factories filled with busy machines, and treat between 5000 and 6000 tons of copper rock per day.

There are two immense pumps lifting a quantity of water, sufficient for one of our large Eastern cities, for the mill work.

The shops of the mine are in the main duplicated at the mills. An idea of the importance of this mine to the people may be obtained when it is stated that the Calumet and Tamarack mines together support a population of about 13,000, and the mills about 5000 more, speaking some seventeen different languages, who are being transformed into American citizens. They have their schools and churches, and furnish a market for farm and garden produce. All of this would not have existed but for the mines.

The development of gold placer-working is of interest and deserves to stand out by itself. The miner washed his sand or gravel in a pan; settling the gold to the bottom, and working off the gravel over the edge, he recovered a few particles of gold from each panful. It was back-breaking work, and he could only pan perhaps a few hundred pounds per day. The rocker or cradle with little depression or riffles followed with two tons per day, the tom or little sluices with riffles with ten or twenty tons, the riffle-sluice with a capacity measured only by its width and the quantity of gravel that could be brought to it. The increased quantity was obtained by the giant or jet of water issuing from a nozzle five to nine inches in diameter under a head of 200 to 1000 feet, capable of moving thousands of tons of gravel to the riffle-sluice several miles long, saving many thousands of dollars of gold. At this stage an opposing interest appeared in the farmer on the low land whose river was filled with débris and his farm flooded with water. To overcome this difficulty, various schemes of retaining-dams were devised and found to a very limited degree successful. Later came the dredger, which for certain deposits holds the field to-day. It is a flat-boat floating on its own little pond with a chain-bucket dredging-tool at the bow, a screen and riffle-tables to save the gold, and a stacker or elevator to pile up the refuse at the stern. This boat performs the curious feat of traveling across the country carrying its pond with it, cutting away the gravel in front and building it up behind. These dredgers mine, for about six cents per cubic yard, 2000 yards per day, and the gravel may run from ten cents to one dollar per cubic yard.

The dredger is self-contained, saves the gold, and does not infringe upon the rights of the farmer.

Summing up Development

And so through the various stages, the development of mining has gone on until we have the large modern mine equipped with fine machinery for excavating and tramming, those with powerful hoisting engines for lifting hundreds of tons from thousands of feet in depth, with great ore-breakers for crushing the rock, and fine concentrating machinery for enriching the ore; furnished, also, with monster pumps for removing the water from great depths and for furnishing the concentrators and fans for taking out the powder smoke and other dangerous gases, preserving the lives of hundreds of men; furnishing problems for the mechanical engineer in the handling of great masses of material with rapidity and economy; with problems in surveying the most difficult the civil engineer ever has to encounter, for example to fix exact property boundaries or to unite subterranean galleries thousands of feet below the surface, and in hydraulics for the handling of immense volumes of water to be made use of or to be got rid of, and in electricity for the transmission of power many miles from distant mountain streams to excavate, tram, hoist, pump, ventilate, and light the mines, the construction of great buildings for housing his machinery or his plants; adapting crushing and concentration plants for the most successful concentration of the ore and of smelting to extract the metal with the least cost and greatest efficiency and purity; the wise selection of subordinates for efficiency and loyalty; the handling of the men to get a day's work and keep them contented and happy; the financiering of the mine to get the money for opening up and developing, to keep up the dividends and the repairs and development work and sinking fund all at the same time so that the owners may feel that they get interest on their investment and get their money back after the mine is worked out.

This completed picture seems to call for a combination of mineralogist, geologist, of a mining, mechanical, civil, and electrical engineer, of a chemist and metallurgist, of a builder, a manager, and a financier, a man with literary ability and personal magnetism. Such a combination seems absurd at first glance, life is n't long enough to accomplish it, and yet, with certain provisos, it is exactly what is done.

Mining enterprises occur of all sizes from very small to very large. It transpires, then, that in the small mining venture the mining man must be able to handle all the departments specified; while on the other hand in a large mine he has many departments with department heads, mechanical, civil, and electrical engineers, builder, chemist, and others, but he has to direct all, so that a good working knowledge along the various lines is quite as important if not more so than in the case of the smaller mine.

The question may now well arise, On what lines and how should a man fit himself for this class of position? How can he best master this wide relationship of the mining engineer to the other fields?

I will attempt to answer this question in some detail. The accomplishments he needs are comprised substantially in this list:

English: He should speak, read, and write the English language well, to convey intelligently his plans and suggestions to his superiors, his wishes to his subordinates, and to read up his authorities on matters professional.

Language: He should know foreign languages for ease in conversing with foreigners and reading their works.

Literature: He should be familiar with good literature, to give him ease in meeting people.

Logic: He should understand the basis of argument, the relations of cause and effect, both as to men and things.

Mathematics: He should be able to use mathematics for clear thinking, demonstrating, and estimating.

Physics: He should be familiar with the laws of physics; mechanics, heat, light, electricity, sound, pneumatics, hydraulics, to help him act wisely in professional matters.

Chemistry: He must understand the laws of chemistry, not only as to effects of humid operations but as to effects of fire.

Drawing: He must have a good working knowledge of drawing for clear thinking, for making designs, for expounding plans to others, and for directing work.

Power: He must know the prime movers in their operation, their economy, and efficiency.

Machinery: He must understand the transmitting machinery, to bring his power to the commercial end point with the greatest economy.

Railroads: He must understand the laying out and running of railroads, including cuts, fills, tunnels, grades, tracks, switches, bridges, rolling-stock, locomotives for conveying his material.

Surveying: He must understand surveying for defining underground boundaries, for meeting underground workings, for locating, grading, roads, buildings, machines, water-pipes, ditches, wires, etc.

Mineralogy: He must know and be able to determine the minerals of economic importance, to recognize and take advantage of values when and where opportunity occurs.

Geology: He must be skilled in geology for locating deposits, in preliminary work, and for predicting the whereabouts of ore-deposits in existing mines.

Materials: He must know the materials of engineering — what, when, where, and how to use them, and also to preserve them.

Structures: He must know the principles upon which structures are built and the practice in building.

Law: He must be up in the law of contracts and of titles, to see that his company gets its rights in purchasing materials, selling materials, and in ownership of its property.

Labor: He must know the value of a day's work and see to it that his men know that he knows. He must study the labor problem so as to deal wisely in the time of need.

Business: He must understand the principles on which business is transacted so as to get fair treatment and yet keep his customers.

Finance: He must understand the principles of banking, and of establishing and holding credit.

Mining: He must understand the mining operations, safely to mine, prepare, and ship the ore or coal.

Metallurgy: He must understand the chief metallurgical operations for the common metals so as to suit the metallurgist with his ores or become a metallurgist if opportunity and inclination lead him that way.

He will equip himself along as many of these lines as he can, and establish connections for supplying those which he has not acquired.

We will now look to see what he does in return for favors received.

If we look about us, scarce an object can be seen to the production of which the miner and metallurgist have not contributed. Metal objects owe their strength to the iron or the copper alloys of the miner, their purity to the metallurgist, their beauty and decorative effect to gold, silver, brass, bronze, stone, pottery, and wood, all of them got from the mine or fashioned by metal tools from the mine. Our carriages, automobiles, locomotives move us from place to place; our wires carry our telephone and telegraph messages; our sewing-machines make and mend our garments; our saw-mills make the lumber for our houses; our harvests of wheat, corn, and potatoes, our pots and pans, knives, forks and spoons for cooking and serving food, all either themselves come from the hands of the miner or the tools for fashioning or getting them are the result of his labor; our diplomatists after doing their all with wits come as last resort to the battleship, the guns, the riffles, and the lead from mines. And, finally, the medium of all finance with which we run our mines, our factories, and with which we purchase our wares and supply our wants, whether for peace or war, is the gold from the miner's pick and shovel. We may say, then, that the work of the miner reaches the interests of all.

Coming now to the schools in which he is to prepare himself for his life's work: there appear to be three plans of education which deal with the problem of equipping men along mining engineering and metallurgical lines.

(1) The school of practice, supplemented by the correspondence school.

(2) The technological school.

(3) The university followed by the technical school.

Some pupils of all three plans reach the highest pitch of professional responsibility, as the whole question is more one of the man than of the plan. We have no reliable statistics showing percentages of success of or proportional success. One is obliged to resort to opinion, and the opinion of no two may agree.

The especially strong point in the first plan is the intimate knowledge that is acquired of the employee class and of the minute details, — knowledge of work which is obtained in the doing of it.

The especially weak point in the first plan is that it is narrow and that progress is slow. Experiments may be more expensive to the company and in consequence a greater conservatism rules and lack of readiness to adopt new ideas even when proved.

The second plan has the advantage that in four years from the high school the student is equipped and strengthened along a sufficient number of lines so that he can do the rest if he is reasonably energetic and sensible. He may tumble down because he has not made a sufficient study of the employee class. He can perfectly well avoid this, however, by taking hold of manual work as a laborer or a miner for a sufficient time to acquire the knowledge of what men are, what they do, and how they do it. He may tumble down because he has not made a sufficient study of how to deal with men who are his superiors, or of the capitalist class. This he can avoid if he will accept every opportunity to meet men, and keep himself well read up on the progress of his profession and on affairs of public interest, together with reading of good literature.

The third plan takes six, seven, or eight years from the high school and may lead to crystallization of the man even to the point of inability to adapt himself to what is wanted of him. This is the weakest point of this school. His best prevention or cure will be to take hold of work as the laborer and miner and make an intimate study of the employee class by doing the work side by side with them. In regard to the professional work, the third plan may or may not have an advantage over the second in consequence of maturity. The logical advantage may be offset by the time lost and by hurtful crystallization. "The college student may have learned to do nothing thoroughly well, and if he enter the scientific school after graduation may be less fit to do its work than he was four years earlier. He may have learned to depend on text-books rather than observation, and on authority rather than on evidence." The strongest point of the third plan is the knowledge the student gets of men of influence who later become capitalists. If, however, the member of the second school is energetic and sensible in working for this, it is doubtful if even this is a sufficiently strong point in favor of the third plan to give it preference over the second.

The circumstance of opportunity may come about differently in these plans of education. A fine engineer may be hidden away in some obscure position who would, if circumstances had favored him, have become renowned all over the world by the greatness of his capacity. The third plan may have some advantage in this respect, in finding out the great man and bringing him to the front. This is more an incident than a virtue of the third plan due to the men who follow it.

PRESENT PROBLEMS IN THE TRAINING OF MINING ENGINEERS

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"THE man is always greater than his work." The training of the men who are to develop the mineral resources of the world is the most important problem connected with mining engineering. It becomes ever more important to civilization as the mineral wealth of the earth approaches exhaustion. I have therefore decided to consider a few of the more important problems arising in the training of the mining engineer, and especially those arising in America.

The Peculiar Nature of Mineral Wealth

Mining and agriculture are the two fundamental arts. Without the latter our existence would be precarious; without the former, our civilization impossible. Agriculture furnishes that regular supply of food and raiment which leads to the growth of large communities in which cultivated leisure first becomes possible; while mining furnishes the metallic thread from which is woven that complex fabric we call civilization.

But in these two arts the conditions for success are widely different. Most of the crops that the farmer reaps may be harvested year after year, and, the proper fertilizers being added, he may continue the annual harvest indefinitely, while, as a result of cultivation, his farm becomes yearly more valuable.

But the crop the miner reaps can be harvested but once in the history of the race. Our mineral wealth has taken unknown ages to mature in the bosom of the earth. The ripened fruit can be plucked but once. There are no fertilizers for worked-out mines. It never pays to work over a mine that has been "robbed," either through ignorance or lack of skill; and a worked-out mine is utterly worthless.

These differences between the two kinds of natural wealth have been long recognized, and have led in the Old World to a very conservative policy in the utilization of mineral wealth.

Though the fragmentary history of primitive mining-law is full of contradictions, it would seem that the development of the mineral wealth of the world was at first everywhere due to the free initiative of the miner, whose exertions were stimulated by the right to possess what his energies discovered. But everywhere in the Old World the mailed hand of the sovereign soon seized this important source of wealth and power. It was used at first exclusively for his own benefit, but as more enlightened views of the duty of the sovereign to his people spread through Europe at the end of the Middle Ages, these special rights and privileges have been used more and more for the benefit of the whole people. At the present time in some of the Continental countries individual initiative and ownership has asserted itself once more; still, it is generally true that in most of the countries of Continental Europe the mines are either owned or are worked under the direction of the Government. In these matters the policy of Great Britain and her colonies has been, in general, intermediate between that of the United States and of Continental Europe. Hence, in what follows I shall dwell chiefly on the differences between Continental and American customs.

Continental and American Mining-Schools

When European mining-schools were first organized they also came naturally under Government control, and there consequently resulted a close union between the mines and the mining-schools. This in turn led to many other important consequences. A regular career was opened for the graduates of the mining-schools either by their direct employment in mines operated by the Government or in the inspection and direction of the working of mines under Government control. As a consequence of this policy, well-trained men have always had the management of the mines under a sort of civil service system. And also a wise conservation of the mineral wealth of these countries has resulted; the mines are worked systematically and have often kept producing a steady output for several hundred years, while in our country they would have been worked-out and abandoned in one or two decades. While, according to our ideas, there are drawbacks to the Continental policy, it certainly lends a restraining influence to the natural uncertainties of mining life; it gives a more certain tenure of office to the mining officials; and, consequently, results in a more conservative policy in the management. It effects a more complete extraction of all the ore in the deposit, a better avoidance of wastes and a more complete utilization of all the side products. On the whole, the system, when wisely administered, leads to excellent results.

Its effects on the early development of the mining-schools were also favorable. The close relation between the mines and the mining-schools made it easy for the one to assist the other. The graduates of the mining-schools were as sure of employment in an honorable profession as are the graduates from our Government military and naval academies at West Point and Annapolis. Historically, this connection has lent the air of distinction that clings to the profession of the mining engineer apart from his function as a mere money-getter.

On the Continent two grades of mining-schools have grown up. The *Bergschule* and the *Bergakademie*. The *Bergschule* trains working miners for the duties of mine foremen, while the *Bergakademie* trains young men of the educated class for the duties of the mining engineer.

The system here outlined possesses many advantages and is admirably adapted to the countries where it originated. But it would be impossible in America. In the first place our Government gives away its mines and does not attempt to control either them or the mining-schools. No official connection either exists or is possible between them. Moreover, though there is much to be said in its favor, the sharp distinction drawn between the *Bergschule* and the *Bergakademie* in Europe is at variance with American ideals of democracy.

It has become an axiom with us that not only genius, but also talent, ability, and capacity of any kind, are too precious to the entire community to allow them to go to waste. We err, indeed, by going to the other extreme. But there is no doubt that the wonderful industrial progress of America is largely due to that equality of opportunity that is here practically open to every young man of ability.

The American Temperament

It has often been claimed that the American temperament is due to our peculiar climatic conditions. As a matter of fact nearly all the climates of the globe characterize our country. And in order to disprove this theory one has only to cross the narrow line that bounds our country either to the north or to the south to find a relief from the strenuosity of the American temperament. The American temperament is due, not to climatic conditions, but to a mental attitude toward life. When a man feels that his future depends not so much upon his own efforts, but mainly upon the position to which he was born, he is, if not contented with his lot, at least more likely to be reconciled to it; for he feels it idle to waste himself in useless effort. But if you can convince such a man that there is no limit to his ambition but that of his own powers, you have fired him with the most powerful stimulant that can influence human nature. It is this stimulant, working day and night for over a century upon men descended from every race in Europe, that has produced the American temperament.

It is a temperament that was not unknown in Greece in its great democratic days. Republican Rome felt it too. But in monarchies its influence is mostly confined to the army and the navy. For in war times the best man must be had regardless of his birth. Napoleon overran Europe by declaring to his men: "Every soldier carries the Marshal's baton in his knapsack."

The Rôle of "the Practical Miner" in America

Nowhere in America has this influence been more keenly felt than in the mining industry, particularly in the Western States. The policy of our Government in throwing open to the hardy prospector its ownership in the mineral wealth of these states has stimulated men without previous technical education and training to accomplish what in older countries would be regarded as physical impossibilities.

It is true that the path has been marked with waste of money, labor, and life. Blunders, failures there have been, and still are, innumerable. But the accomplishment is all the more remarkable when we recognize these facts, for it testifies to the almost superhuman energy with which these obstacles have been overcome.

We are greatly indebted to the Old World for its contributions to the mining and metallurgic art, but we are beginning to repay the loan with generous interest. And, to tell the truth, it is largely due to the plain average American, without college education or training, that many of these advances have been made. Every one who has mixed much with American miners has met and honored many such uncrowned kings. *And unless the graduate of American mining schools is ready and willing to meet with this kind of competition without fear or favor, he will surely and deservedly fail.*

This was the first great problem that confronted the American mining schools and it has proved their greatest advantage. There is no royal road for their graduates. They cannot depend on the Government for places in the mines, because the Government neither owns, works, nor attempts to control the mines. Neither can they look to their diplomas as a guarantee of employment.

The American attitude on this question has hitherto been very different from the European. Credentials, degrees, diplomas, and recommendations that in Europe carry great weight, in America often receive but scant attention. The American often amuses himself with titles, but deep down in his nature is an instinctive distrust of any one who takes them seriously. Among the men who have done most to develop the mineral wealth of our country this feeling is particularly strong. What a man is, is more important to them than who is he. What a man knows interests them but little; it concerns them much more, what use he can make of this knowledge.

Herbert Spencer, a radical in so many of his opinions, was quite in sympathy with this point of view. I quote from his *Autobiography*, vol. I, p. 199, beginning with a passage from a letter to Herbert Spencer from his father:

"'I am glad you find your inventive powers are beginning to develop themselves. Indulge a grateful feeling for it. Recollect, also, the never-ceasing pains taken with you on that point in early life.'"

Herbert Spencer then adds:

"The last sentence is quoted not only in justice to my father, but also as conveying a lesson to educators. Though the results which drew forth his remark were in the main due to that activity of the constructive imagination which I inherited from him, yet his discipline during my boyhood and youth doubtless served to increase it. Culture of the humdrum sort, given by those who ordinarily pass for teachers, would have left the faculty undeveloped."

Footnote by Mr. Spencer: "Let me name a significant fact, published while the proof of this paper is under correction. In *The Speaker* for April 9, 1892, Mr. Poulteney Bigelow gives an account of an interview with Mr. Edison, the celebrated American inventor. Here are some quotations from it: 'To my question as to where he found the best young men to train as his assistants, he answered emphatically: 'The college-bred ones are not worth a ——! I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work.' Mr. Edison did not conceal his contempt for the college training of the present day in so far as it failed to make boys practical and fit to earn their living. With this opinion may be joined two startling facts: the one that Mr. Edison, probably the most remarkable inventor who ever lived, is himself a self-trained man; and the other that Sir Benjamin Baker, the designer and constructor of the Forth Bridge, the grandest and most original bridge in the world, received no regular engineering education."

Mr. Spencer might have added himself to this list of remarkable self-made men, for his schooling, though excellent as far as it went, was very meagre, and he made himself what he came to be.

In the words: "*I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work,*" Mr. Edison has put his finger with singular acuteness on the principal failing of improperly trained college students. The reason why they are not willing "to begin at the beginning and give their whole heart to the work" is because their education has often been so exclusively theoretical that they are filled with the conceit of learning, and they have an inordinate idea of their untried abilities. Hence their unwillingness "to begin at the beginning." They feel that they ought to begin at the end and be put in charge of everything. If, in their training, theory and practice had gone hand in hand, this conceit, which is natural to all young men, would have been soon dissipated by the hard realities of practice, and the young men would have been more willing "to begin at the beginning," and more ready and able "to give their whole heart to the work."

At the same time I cannot help thinking that Mr. Edison must have been unfortunate in his choice of "college-bred assistants," or in the colleges that trained them; for in opposition to his experience may be quoted the practice of a large number of his important rivals in the electrical business and of an increasing number of iron and steel railway bridge construction, and mining and smelting companies, to draw upon the graduates of engineering schools for their assistants; and where they wisely insist on the men beginning at the bottom and working their way up according to merit, the results have been, on the whole, more and more satisfactory as the engineering schools have adjusted themselves more closely to their environment. I have given these strong statements of the failings of college-bred men, not to indorse them, but because they contain an important truth that must be recognized and met.

This condition of public opinion has from the very first forced the American mining schools to stand on their own merits. Whatever success they have achieved has been due to this hard necessity.[1] The atmosphere surrounding European mining schools is so different from that in America that graduates from such schools have always found in America much to be unlearned. The American mining schools have already adapted themselves so well to their environment that this year, for the first time in nearly a century, there were no American mining students in the great Saxon Mining School at Freiberg. And already some of the American mining schools have exceeded in wealth, in equipment, and in attendance, this most famous of all mining schools.

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[1] I append in this connection the following concise and caustic note from the *Engineering and Mining Journal*, p. 403, June 12, 1880, which shows the condition of affairs in America only 25 years ago. The hope expressed in the last paragraph has since been largely realized to the benefit of all concerned.

"A correspondent writes us, asking 'If it is absolutely necessary to be a graduate of a school of mines before being able to engage in the business of a mining engineer.' Certainly not; in fact, before engaging in the business of mining engineering it does not appear to be absolutely necessary that a man should know anything at all, as our correspondent can very well satisfy himself by visiting nine out of ten of the mines nearest to him, wherever he may be. Had our correspondent asked, whether it would be desirable that a man should be a graduate of a school of mines before engaging in mining engineering, we should have answered in the affirmative, for the simple reason that the course of study in a school of mines is calculated to give the elementary education necessary for a mining engineer, and, other things being equal, should give its recipient an advantage over those who have learned the business only in practice. The course of study in a school of mines is not, however, sufficient to qualify a mining engineer to take charge of important works; but it forms an excellent foundation upon which to build a practical knowledge of the business.

"Many of our mines are now under the direction of competent engineers and the results of this policy are justifying the hope that, before very long, all companies of good standing will place their mines in charge of men specially trained for the discharge of the responsible and important duties of a mining engineer."

Is Theoretical Training Worth While ?

But, it may be urged, if practical men without theoretical training have accomplished so much, what is the use of theoretical training? Why not confine the education of the mining engineer to the purely practical part, omitting all the theory? The answer is not far to reach. The purely practical man has indeed accomplished wonders, but at the cost of enormous waste of money, labor, and human lives. For every success that he has made there are a thousand failures which only the thoughtful notice. There is no profession where practical experience is more essential than in mining, but the necessity of a sound scientific training is even more indispensable. A hard-headed Arizona miner once put the matter very tersely when the superiority of the "practical man" was being strongly urged, by saying: "I have had thirty years' practical experience in mining, and I would give twenty-five of those years to have had a good technical education to begin with." He was clearly right, for a man well trained in fundamentals has a broader grasp and can more intelligently and rapidly utilize his experience than a man without this training.

Either theory or practice alone is helpless; united they are invincible. And the brilliant success of the American mining engineer in so many fields has been because these two important elements have been so thoroughly blended in his training.

Specialization, How Much and When ?

This problem arises from the great breadth of training which has been necessary to the American mining engineer. Like the soldier or sailor, he must go to the ends of the earth. His work often lies beyond the borders of civilization, where, like Prospero upon his lonely isle, he must conjure up his resources from the vasty deep; and he must act in turn as geologist and as civil, mechanical, hydraulic, electrical, mining, or metallurgical engineer. The problem is: What degree of specialization shall be undertaken in an undergraduate mining course? Shall we endeavor to turn out at graduation specialists, each completely equipped for work in some narrow line, or shall we rather attempt to establish a broad basal training in the physical sciences on which the future engineer may safely build, as circumstances may require?

The former system is the European practice, such parallel courses as mining engineering (further subdivided into coal- and metal-mining), metallurgical engineering (also subdivided into two branches), mine-surveying, mine-geology, and the like, being commonly recognized departments within which the student specializes in an undergraduate course.

In an old community, where the mines are under Government control, and customs have crystallized, such a specialization is wise. Each student can estimate with certainty the need for the specialty he chooses, and be sure of employment in his own line.

But under American conditions (with a few notable exceptions, where conditions have become relatively stable), it is unsafe to specialize too soon and on too narrow a basis. Here the mere specialist, outside of his specialty, is as helpless as a hermit crab outside of his shell, and unless he possesses the ability to adapt himself speedily to a rapidly changing environment, is sure to go under. The present age in America is one of rapid change in all industrial and engineering methods, such as has never been seen in the world before. Old established processes are being continually swept aside and replaced by new ones. These changes occur with kaleidoscopic speed and unexpectedness; and the man who has painfully armed himself with precedent and ancient lore finds himself hopelessly beaten before he can even make a start in the race. The American has always been characterized by his fertility of resource and power of adaptation. This has been his strength; his weakness has been his impatience to plunge into practice without a sufficiently broad and deep scientific training.

Fundamentals First

I believe that we can trust to the American instinct of adaptability without much further attention. But that which is most necessary is to insist more and more on a solid foundation of scientific training to begin with. If we can secure for the American mining student a foundation training broad, deep, and thorough in mathematics, physics, and chemistry, he needs little else to make him invincible. The mining engineer must have a broader basal training than either the civil or the mechanical engineer, even though he specialize less. Mathematics, physics, and chemistry are necessary for all engineers; but for the civil engineer mathematics is fundamental, for the mechanical engineer physics is equally so, while for the mining engineer we must not only add physics, but also chemistry, with her closely related allies, mineralogy and geology.

The training of the mining engineer cannot be too thorough in all these subjects. Each is an essential support to any superstructure that he may desire to build in the future.

Mathematics should include the differential and integral calculus, the theory of probabilities, and the methods and criteria of approximations. A firm grasp of space-relations as developed in descriptive geometry is peculiarly important in following geological structure and vein-formations in the deeps of the earth. The mathematical work should be made familiar by numerous applications to concrete cases in which numerical results should be insisted upon. In this connection it is particularly important that the engineer should be made to realize that the most important part of his numerical result is the position of the decimal point, and only after that, the value of the first significant figure. Mathematical instructors too often neglect this, to the engineer, most vital matter. The sense of it should be made instinctive. It is much more important that mathematical instruction should be thorough as far as it goes than that it should feebly cover a large territory. The subject should be so thoroughly mastered that it comes to fit the hand like a well-worn tool.

No man is fit to teach mathematics to engineers who has not had some experience in its applications either to engineering, to physics, or to astronomy. For only such a man knows just what to emphasize and what to omit, how to sympathize with, and how to inspire his students.

Men of prime ability in the mathematical faculty are absolutely the first essential in any engineering school. It is wonderful how difficulties melt away like wax in the fire with a really able mathematical teacher. By such a teacher mathematics can be made as interesting as a romance to the average man; while it is often regarded as hopelessly difficult merely on account of the poor hands in which it is placed. To make new discoveries in the field of mathematics requires genius of a high order; but to master all the mathematics necessary for the intelligent practice of engineering requires no faculties beyond those of a logical mind, a certain power of imagination, and a reasonable degree of application. I have always found that the students who do well in mathematics do well in everything else that requires close thinking.

Instruction in physics and in mathematics should go on side by side; and the two courses should be so arranged that the mathematical principles may be at once applied to physical problems of a useful nature. The importance of actual numerical results should be always insisted upon. The student should be trained in the arts of observation and in inductive as well as deductive reasoning. He should acquire practice in the theory of approximations and should form the habit of judging or "weighing" his own results and of checking them by independent methods.

While the whole field of physics is important, the fundamental conceptions of analytic mechanics (acceleration work, kinetic and potential energy) and their applications in hydraulics, thermodynamics, electricity, and the like are vital, and cannot be too much emphasized.

Instruction in chemistry should be given parallel with mathematics and physics. It offers a fine training in inductive reasoning. Besides the usual courses in general and analytic chemistry, the modern methods of physical chemistry, as developed by such masters as Arrhenius, Ostwald, Nernst, and van 't Hoff should be brought to the attention of the student, as soon as, by his collateral training, he is made able to understand them. It is not too much to say that the hope of the future, not only in biology, medicine, and hygiene, but also in physical geology, the science of ore-deposits, and the art of metallurgy, lies in this direction.

Such subjects as drawing, surveying, and mapping may also be carried on simultaneously with mathematics and physics, each supplementing the other. Similarly, assaying and mineralogy give a new interest to chemical principles, to which they serve as useful applications. Geology, itself, important as is this noble subject, not only through its intrinsic interest, but also in its practical bearings, is really only an application of the principles of physics and chemistry to the study of the evolution of the earth. And it can be mastered only by him who has this training to build upon.

The same is true of every branch of engineering. Each is only the outgrowth of the application of the principles of the fundamental physical sciences to the needs of man. He who has this training has the master-key to the door of every industry.

The necessity for thoroughness in this fundamental work cannot be too much emphasized in American mining schools. The impetuous preference of young Americans for what they deem "practical" is a serious hindrance to real achievement; and the only way to remove it is to convince them at the very start of the power and value of science. This can best be done by leading them, from the beginning, to apply science to some useful purpose. In short, they must be taught by experience the truth of Ostwald's saying: "The science of to-day is the practice of to-morrow."

There is much to be said in favor of the study of science for its own sake. We have all sympathized with the sentiment of the mathematical professor who "thanked God that he had at last discovered something that never could be put to any practical use." Still, it is a healthful instinct that leads most men to estimate the value of ideas by the use that can be made of them, and whether we approve it or not, the world will continue to do that, and we may as well adapt our plans to the fact.

To the man thus fundamentally trained nothing is impossible. He may still need to be made familiar with the general scope of each of the main branches of engineering, their relations to each other, the nature of the problems that each is called upon to solve, and the leading methods which, in each branch, have stood the test of time; and he should be made sufficiently familiar with the literature of the subject to know where to go for needed particulars; but any attempt to cram his memory with the details of methods that may become obsolete, before he is called upon to use them, is a distinct and fatal mistake.

The Organizing Faculty

The successful engineer is a creative artist in the use of materials and energy. In this class, he stands first who with the smallest means produces the greatest results. Success will come most surely to him who clearly sees the nature of each concrete problem, and, from the widest outlook, chooses just the right methods, materials, and forces of men and nature, to bring his undertaking to a successful issue.

Among engineers the creative or organizing faculty is a natural gift as rare as any other kind of genius. But fortunately it is a faculty most Americans have, at least in embryo, and it can be cultivated. All the work of a mining school, whether in the basal sciences or in the technical branches, may be utilized to develop it. Instead of possessors of encyclopedic erudition, there is needed a type of man that may mechanically remember less but can do more. Such a man learns to analyze each problem that comes before him; when necessary, he runs down the literature bearing upon it; selects the good; rejects the bad; supplies by ready invention the missing link; decides what must be done, — and *does it,* cleanly, rapidly, and with certainty, while the "encyclopedia maniac" is still digesting his erudition.

This kind of training, repeated again and again with every subject studied in the college course (at first in small and simple problems, later in larger and more complicated ones), does more to create the engineering faculty than anything else that can be devised. It is only by actually doing things that we learn how to do them. Action must follow reflection, and reflection must precede action for successful and useful life. Unless action follows reflection, life is "sicklied o'er with the pale cast of thought." Unless reflection precedes action we have all the ills that follow impetuosity, of which anarchy is the final and the bitter fruit. From this point of view the training of engineers has a moral effect on the whole body politic, since it tends to create a solid, well-balanced element in the community. Nothing develops a good man sooner than responsibility, which forces not only reflection, but action also. And the sense of power that comes with the successful exercise of the creative faculties in the engineering arts is one of the purest and keenest pleasures of which our nature is capable.

The greatest service those in charge of the higher technical branches of the mining school can render their students is to show them how to apply their scientific knowledge to such practical problems as come before them. He who can do this for his students, and can give them a taste of that sense of power that comes from a mastery of the forces of nature, can trust them to go the rest of the road without a finger-post to point the way.

Personal Contact with Working-Conditions

I have said that the mining engineer should learn to see clearly the problems that he must solve; that he must be familiar with the materials and the forces, not only of nature, but of human nature, with which he must work. How shall he gain this knowledge? There is only one way: To become familiar with them by actual contact.

Should this experience come before, during, or after the college course? It is most useful when it comes in all three ways. But coming only after the college course, it is altogether too late. Before that course, it can be usually gained only at the sacrifice of that general training, particularly in the languages and the humanities, that is so important to us all; and, moreover, before college-age the student is usually physically too immature to undertake such work. For these reasons it is usually best to let this experience begin with entrance into the mining-school. In each college year, as commonly arranged, from three to four months are given to vacations, which, occurring at regular periods in summer and winter, are admirably adapted to a progressive course of practical work in surveying, mining, and metallurgy, in which the student can familiarize himself with practical conditions in different localities. For the reasons already given, this work should begin with the school course, and be carried on progressively, at regular intervals, with the theoretical work. It is thus practicable for the student to gain nearly a year of experience in a considerable range of methods. He is thus in a position to determine his own fitness for the work; to learn the branches for which he is best adapted, and for which there is most demand; and to make acquaintances that will be useful to him afterwards. If he shows aptitude for the work, he is reasonably certain of finding the place for which he is suited; and if he does not, he can adjust himself to some other calling without further waste of time.

The importance of this training for the mining engineer is greater than in any other branch of engineering; for the conditions that he must meet are entirely different from those of any other calling. But it has been much more difficult to secure it under American than under European conditions. Besides the lack of official connection between the mines and the mining schools, there has been a strong prejudice against college students on the part of practical men. This is partly due to experience with men trained exclusively in the old classical course, and almost helpless in practical affairs, because absolutely without knowledge or sympathy with nature. But it is also partly due to the self-assertion, flippancy, and conceit of which young men just out of college are often guilty.

The "Mining Laboratory"

Several solutions have been proposed to meet this difficulty. The first and most original is the so-called mining laboratory, perfected through the pioneer work of Prof. R. H. Richards of the Massachusetts Institute of Technology. This has since become a prominent characteristic of American mining schools generally, and is now being adopted in Europe. According to this plan, the leading operations of crushing, concentrating, and working ores are executed by the students on a small working-scale in the laboratories of the school itself. In this way the schools have become partly independent of the mines, so far as the study of metallurgy and ore-dressing is concerned. In purely mining practice the problem is more difficult. I have for ten years, with some success, made an attempt in this direction, so far as rock-drilling and blasting are concerned. For this purpose, a mining laboratory has been provided, in which the operations of sharpening, hardening, and tempering drills, and the single- and double-hand drilling of blastholes, as well as machine-drilling, are illustrated on a working-scale. Later, with the aid of an experienced miner, the operations of blasting are conducted by the students in a neighboring quarry. In the new mining building, provided for the University of California by the generosity of Mrs. Hearst, it is proposed to extend this work, as far as practicable, to other branches. These devices have all proved very useful in familiarizing students with important current methods, under conditions where they may be controlled and studied in detail, even better than in the hurly-burly of practice. The mining laboratory is one of the most important of the efforts of American schools to adjust themselves to their environment.

The Summer School of Practical Mining

But helpful as this method has proved to be, it still fails to bring the student face to face with the actual conditions of mining practice. The next important step was taken by Prof. Henry S. Munroe, of the Columbia School of Mines. For many years he has devoted much labor, with notable foresight, judgment, tact, and discrimination, to the system now known as the Summer School of Practical Mining. To him, more than to any other one man, we owe this very useful adjunct, which has been adopted, with various modifications, by most American mining schools. It is an outgrowth of the geological excursion, so long practiced in German mining schools. But here it has been made to comprise the study, by a body of students, under the direction of their professors, of the leading operations of mining, dressing, and working ores. One or more mining districts and several mines are visited, during a trip of a month or more. Surveys are made; sketches and notes are taken; and the student begins to acquire a first-hand knowledge of many conditions which he must afterwards meet.

An interesting modification of this method has just been attempted jointly, at the suggestion of Prof. John Hays Hammond, of the Sheffield School, and under the direction of Prof. H. S. Munroe, of Columbia, by the mining schools of Columbia, Colorado, Harvard, the Massachusetts Institute of Technology, and Yale. It consists in hiring a mine for the summer, and putting the students at work under proper direction at the various operations of practical mining. In this way the mine for the time being is turned into a sort of school for the young men. This change certainly has many advantages. It comes as near the European conditions as is possible in America. It enables the operations of the mine to be subordinated for the time being to the needs of instruction. This, for beginners, is certainly a great advantage. The method is, however, an expensive one; and several years of experience are necessary before it can be finally judged.

There is another modification of the summer school idea, perhaps even more difficult of general application, with which I have had the most experience, and from which I hope much in the future. I began by visiting with my students various mining districts each year; but I found in this plan not only many advantages, but also many serious difficulties. One of the most fundamental of the latter was, that there is an important element which a man does not get by merely looking on. He often thinks he understands a thing that he sees another do; but such superficial knowledge is not to be trusted. It may suffice for amateurs and *dilettanti ;* but real professional knowledge and power are not so obtained. It leads to that false sense of knowledge that makes practical men so disgusted with the man just out of college. It is the thorough, ingrained mastery which long familiarity with his work has given the practical man that makes him superior in any emergency to the mere "looker-on in Venice." Moreover, traveling with a large body of students tends to emphasize the difference between the students and the miners, and to make each party self-conscious, and, to a certain extent, antagonistic. When many students travel together, they carry with them the college atmosphere, which is the very thing they need most to get away from, in their vacations. It is only when such a body of students is so diluted by dispersal among a large number of mines and miners who are *working* and *not playing* at mining, that they can be made to realize that they are not "the whole thing;" then, and then only, are they in a position to derive any real benefit from their experience.

These views were gradually forced upon me, as they doubtless have been forced on others, by a study of results. Moreover, as the number of students in the classes increased, I found it more and more difficult to secure accommodations for them in any but a few large mining centres. This greatly limited the practicable scope and variety of the work.

But the cause that finally decided me to make a change was the lack of means, among some of the best students, to pay the expenses of such trips, in addition to those of the college course. Some of these men asked to be permitted to work for wages, instead of attending the summer school. This was done in certain cases; and I found at once such an improvement in the subsequent work of these students that I decided to alter my general plan accordingly.

The method, as thus far worked out, is to require that each student shall spend at least a month underground in the study of practical mining. As a matter of fact, most of the students thus spend from six to eight months during their college course, and many of them even more. Each must prepare a well-written account of his experiences, together with an essay, on a subject chosen by himself from among those that interested him most. These papers are read before the whole class and are discussed and criticised by all. Many of them have been extremely interesting and instructive.

The students are not required to work for wages, and are even discouraged from doing so, unless they are physically mature, and have some familiarity with the work. But all are strongly urged to attempt this before they graduate. Most of them need very little encouragement; in fact, they take to it as naturally as ducks to water. There is a time in the development of a young man when hard work seems to be a physical necessity — an assertion of his manhood. It has even come to pass among us that the young man who, from physical or other disability, does not do so, loses caste among his fellows.

There is of course a certain disadvantage in working for wages. A man has to do the same thing over and over again and is usually too tired to think much while doing it. But this objection is easily removed; for when, by a month or more of hard work, a man has established himself and paid his way, it is very easy for him to take further time at his own expense to get a general view of the work as a whole. Some men are of course physically unable to perform manual labor for wages. But unless they are unusually well adapted for the profession in other ways, such bodily weakness is generally an indication that they had better adopt a less strenuous occupation. I have never found that the men have been lacking in mental grasp from having to work; though naturally one cannot do hard labor and take voluminous notes on the same day.

On the other hand, there are certain great advantages in working for wages. It gives a man a just self-confidence, as nothing else can. He feels that no matter where he may be he can hold his own among men as a man. He learns the point of view of the working miner, and how to win his confidence and respect. He gains an inside knowledge of the errors and successes of mine administration. He comes to know the meaning of "a day's work," the tricks and subterfuges by which inefficient workmen seek to evade doing their duty, and the way to treat such cases without unnecessary friction. Such an experience is sure to prove invaluable, when, as he grows older, he is himself intrusted with the management of men. He will be more likely to know how to avoid unnecessary conflicts with his men from having himself "borne the heat and the burden of the day."

As a rule, men without previous experience are put first at loading and tramming cars, and later, at single- or double-hand drilling, or as helpers on a machine-drill; while in small mines they often have experience at timbering or at the pumps. Many of the men are really able to earn full wages as miners, before they get through. Often, when hard pressed for resources, they work a year, or even two years, underground, thus earning enough to pay their way through college. This seems rarely expedient, except in cases of necessity. But there are some cases in which an excess of animal spirits finds in such a rustication a natural outlet, and the man is really made over again by such an experience.

The men are advised not to go in groups, but usually in pairs, since, in case of illness or accident, a faithful "pardner" is a great source of comfort. They are also advised to scatter in a thin skirmish-line over the whole mining region west of the Rockies. Some go as far south as Mexico, others find their way to Cape Nome and the Klondike. Thus, like bees from the hive, they scatter over a wide area; each brings back honey of a slightly different flavor; and all benefit by this richer store.

Many difficulties were encountered, particularly at the beginning, in carrying out this plan. Many still remain to be overcome before it can be perfected. It depends for success, not only on the good will of the miner and the mine-owner, but also upon the discretion and tact of the student. I have always found the miner, and nearly always the mine-owner, willing to help any young man of good physique and good nature who was not overcome with a sense of his own great knowledge and importance. But when a very young man sets out, unasked, to show another man, old enough to be his father, how to run a mine, there is naturally trouble, —as there ought to be. For the first lesson a young man has to learn is the necessity of adapting himself to his surroundings, and of fitting himself into his place in the greater mechanism; and until he learns this, his lot is likely to prove rougher in the mining world than anywhere else.

There is much to justify the prejudice against a man who goes to college simply to escape doing his share of the world's work. Consequently, I have advised my students never to ask for work *because* they were college students, but simply because they were able and willing to earn what they were paid. In short, I have advised them to secure in their vacations the advantages of the "Wanderjahren" of the German apprentice. By scattering over a wide territory they are absorbed very naturally, and, as a rule, without much difficulty. Some of them have learned hard lessons not down in books, but it has done them good.

The men are all advised as to the principal precautions to be taken to preserve their health, the dangers they will have to meet, and how to meet them. They are plainly told that unless they are ready to take the hard chances of the miner's life they had better choose some other occupation.

Among more than a thousand students who have participated in this work during the last fifteen years there have been but two serious accidents. Both of these were fatal. The victims were young men who had been working for nearly a year in the endeavor to earn enough money to pay their way through college. One was caught in a cave. The other, in firing a blast, had his candle blown out by the spitting fuse, and, in the darkness, was unable to reach a place of safety. But these very accidents have served to convince the mining public that the California boys were enough in earnest to face the dangers of the miner's life.

This attempt at a solution of the problem is not presented as a general one; it is probably better adapted to Western than to Eastern mining conditions. It can only be applied when there exist a large number of mining camps within easy reach of the mining school. Its best feature is, that it falls in with the American idea of free initiative. Moreover, it serves admirably to select the fit and reject the unfit without loss of time. It also automatically adjusts those questions of supply and demand that are so hard to settle.

In spite of its many imperfections, the system is beginning to bear fruit. The opposition to college men is growing gradually less. It is found that most of them are in earnest, and are willing and able to work, and that some of them have ability. Before the term of work is over a man is frequently told: "When you have finished college, I may have something for you to do." Many a man has dropped in this way into just the place for which he was adapted.

In short, if the college man can overcome the prejudice against him that often exists all too justly among men of affairs, by showing that he really is a man, modest, willing, and capable, his education will have its chance to count in the end, as it does more easily at the beginning, under Old-World conditions. The only chance to make his start that the American mining student has, is to meet the practical man on his own ground. He can always do this if he has the courage to break the ice. It is better and easier for him to do this before he graduates than afterwards.

Physical and Moral Soundness and the Coöperative Spirit

Experience on these lines has emphasized the importance to the mining student of a sound and, if possible, a robust physique. By this I do not mean heavy muscles merely, but essential soundness of the vital organs, particularly those of digestion, circulation, and breathing, and also the senses of sight and hearing. Important as these possessions are to all, to the mining engineer they are indispensable. An early physical examination by an experienced physician should reject all defective candidates as rigorously as is done in the army and navy. This should be followed by a thorough physical training, whose aim should be the production of a sound and healthy man. Some instruction in the fundamentals of hygiene, the precautions necessary in the use of food and water, the precautions to be taken in malarial regions and some knowledge of the "first aid to the injured," are very useful to men who must often serve as leaders of a forlorn hope in a strange land.

Even more important than physical soundness is moral soundness. It is absolutely necessary that mining engineers not only see the truth, but speak it. Scientific training, when thorough, always develops one important moral trait. It helps to elevate the love of truth into a religion. This is its greatest moral service to society.

In this connection we are all under indebtedness to the late Mr. A. M. Wellington for his able articles on "The Ideal Engineering School."[1]

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[1] *Engineering News*, — 1893.

Speaking of the young engineer, he says: "He must be truthful and worthy of trust, must mean what he says and say what he means. If he cannot do this he must be silent." And again: "All men whose advancement depends on those above them must not only *be*, but also *seem*, faithful to those above them."

He calls attention to the fact that the lawyer, the physician, and, to some extent also, the clergyman, depends for his success almost entirely upon his individual knowledge and intellectual abilities. Such a man may or may not be personally agreeable to those for whom he works; it is his knowledge and his technical skill that we wish to utilize in an emergency. These are his own possessions, and he can utilize them unaided and without the co-operation of others.

But with the engineer this is not the case. His work cannot be done except through the friendly aid, not only of many engineering co-workers, but also through the help of capital and labor, the two most difficult elements in our civilization. From the inception of the original idea to its final completion, men and money, brains and brawn, nature and human nature, must work together without friction for a common purpose.

The young engineer must win the confidence of his superiors by a faithfulness and loyalty, free from subservience; he must secure the good will and liking of his equals by frankness and openness of nature; he must command the respect of his subordinates by his evident mastery of his business, his sense of justice, his freedom from petty meanness, and his fearlessness in the discharge of duty. The man who cannot meet the requirements of any one of these three relations, no matter what his knowledge and technical skill, is sure to fail. And because they possess these qualities in a high degree, many men of very ordinary abilities often succeed as engineers, when men of superior genius lamentably fail.

When men must work together day and night, side by side, in intimate personal contact, where relations of subordination and command necessarily must exist, there must be no friction. Even a slight uncouthness of nature, or rudeness of manner, objectionable personal habits, or lack of tact, become simply unbearable at such close quarters.

All this is most emphatically true of the mining engineer. No men except soldiers, sailors, explorers, and astronomers are subject to such a strain on their endurance.

As was also pointed out by Mr. Wellington, the necessity for the cultivation of the social graces and amenities of life, for habits of personal neatness, for self-control and uniform good nature under conditions of hardship and privation, have always been recognized as essential qualities in the army and the navy. That it is possible to cultivate these qualities, even in the most heterogeneous material, is evidenced by the success of our military and naval academies in producing them in the average American youth. The raw material they have to work on is not different from that which goes to our engineering schools. But the results they attain in this respect are so decidedly better that there is no comparison. In most engineering schools these important qualities are simply ignored, and no attempt is made to cultivate them.

Where, as in many of the so-called "Land Grant Colleges," a certain amount of military instruction and discipline is required, the means exist by which these qualities may be cultivated to some extent. In the University of California such is the case, and I have always found that the mining students who, by attention to such matters, succeed as officers, invariably take high rank in their profession in executive positions. It is one of the few chances men have in college of learning the arts of controlling themselves and others. There is no agent so effective in forcing men to realize the means and advantages of coöperation as rigid military discipline; for the wars and struggles of our race since primeval times have polished and perfected this method till it has reached a high state of efficiency. But it is difficult for engineering schools to give the time and attention to it that is possible in a purely military school.

Another important means of reaching this end is to be found in all athletic sports in which, as in baseball, boating, and especially in football, team-work plays an important part.

Organizing students into parties for surveying and other field and laboratory investigations, where each in turn acts as aid and as chief, is another effective means. In short, any agency that develops the instinct of coöperation, of team-work, of the faculties of self-control, courtesy, fidelity, and faithfulness, will prove effective. It will be more difficult to secure these qualities in America than it is abroad, because of the strong instincts of individualism and self-assertion that are such marked characteristics of American youth. Nevertheless, the uniform success of Annapolis and West Point in these matters testifies to its possibility. There is great room for improvement along these lines in all American engineering schools.

Sundry Minor Essentials

There are also certain minor matters, too often neglected by both students and professors, which are peculiarly important to the young engineer in his first work after graduation, and all of which can easily be mastered in college; such as, neatness in drawing, mapping, and lettering, certainty and rapidity in numerical work; in the measurement of angles and distances in surveying; and in sampling, assaying, and the common methods of analysis. At first, accuracy is more important than speed. But the latter is, in practice, only less important, and should be insisted on from the beginning. A sound judgment on the degree of precision needed for the particular purpose in question is also indispensable. The student should be sure, on the one hand, that his errors do not exceed this limit, and, on the other hand, that he does not waste time in needless refinement when approximations suffice. He should form the habit of always checking his measurements and calculations by at least two independent methods. The only way to insure this standard of accuracy and dispatch is to hold him to the hard standard that he will have to meet in practice, and to make him realize that for carelessness or blunders no explanations can be accepted. Rigid discipline on these lines should begin in the mathematical, physical, and chemical departments, and should run right through the higher technical work with increasing severity. Tolerance of blunders is cruelty in the end.

General Training

The mining engineer needs a certain fundamental training in economics, by reason of his position as an intermediary between capital and labor; his necessary dealings with merchants and contractors; and his handling of questions as to the valuation of mining properties and the financing of mines. Besides the broad questions of money, interest, wages, and other leading topics of economics, it is also important that he should be familiar with the laws of specifications and contracts, of ordinary business usage, the science of accounting, and the law of mines and water.

The broader the general culture with which a student comes to the mining school the better. The minimum entrance requirement should include some familiarity with general history, with the best of English literature, and the command of a simple, clear, and forcible English style. A reading power of the leading modern languages is only less necessary than a mastery of one's mother tongue.

As the training of the mining engineer must of necessity be chiefly scientific and technical, its natural tendency is to put him somewhat out of sympathy with the gentler side of human culture. It is important to counteract this tendency by keeping him in touch with the finer arts, by which life is mellowed, enriched, and ennobled.

Where, as is frequently the case in America, the mining school is an integral part of a great university whose scope includes all the activities of our nature, this end is easily and naturally reached by the association of mining students with other students who are devoting their lives to the arts, to philosophy, and letters. The student is thus forced to become familiar with a wider outlook. Some touch with one of the finer arts, such as music, painting, or sculpture, that will bring out the innate love of ideal beauty that exists in every man, is necessary to a well-balanced nature. Perhaps the most important of these influences is the cultivation of a taste for general literature, whose possession is a refreshment to the soul. The mining engineer who possesses it takes with him to the ends of the earth an inspiration that must make him an agency of moral and spiritual uplift wherever he may be.

Location of Mining Schools

Which is the better location for a mining school, — a mining centre or a commercial one? Successful mining schools have been established in the older countries in both situations; Freiberg, Clausthal, Przibram, and Leoben are examples of the former; and Paris, Berlin and London of the latter. Historically, the first to be established were in the mining centres, which have the advantage of surrounding the student with a professional atmosphere, in which all the activities and ambitions of life gather about this one industry. When means of communication were poor, such a location was almost indispensable.

But such a location tends to make the training of the mining engineer provincial when it should be universal. Moreover, even in Europe, an end comes at last to a mining district, and the mining school becomes stranded in a dying community. Some of the most famous of the European schools are already approaching this condition, which yearly becomes more desperate.

It is for this reason that the modern tendency is in the opposite direction. The most permanent of human institutions are the great commercial centres, made so by natural physiographic features, that facilitate intercourse, which is the life of trade. The capital that develops mines comes from these centres, and the profits from the mines return to them. The enterprise that undertakes great ventures has its source there, and thence, confining itself to no national boundaries, reaches out to grasp the natural wealth of the world.

It is becoming more and more important that a mining school should be located at the heart of things; for it needs to be not only permanent, but permanently strong; to maintain relations with capital not less than labor; and to have a cosmopolitan rather than a provincial outlook and sphere. It is as necessary as ever that the mining school should be in close touch with many operating mines. But in modern times this is much more easily effected from commercial than from mining centres. For these reasons, I believe that in the near future the positions of commanding importance will be held by mining schools located near large commercial centres, particularly when these command not one, but many mining districts.

Over-Supply of Mining Schools in America

In a paper on "The Growth of American Mining Schools and their Relation to the Mining Industry," read at the Engineering Congress at the World's Fair at Chicago in 1893,[1] I have already called attention to the relatively small proportion of miners among the wage-earners of the United States. According to the Tenth Census, the number was only 1.82 per cent of the wage-earners, or 0.63 per cent of the total population. The Eleventh Census showed a similar relation. The figures of the Twelfth Census show the total number of miners and quarry-men to have increased to 1.95 per cent of the total wage-earners, or 0.75 per cent of the population. It is impossible to determine from this report the exact number engaged in metallurgical work, but after a careful study of the data given, a liberal estimate for metallurgical laborers shows that the total cannot be for both industries much more than 2.5 per cent of the wage-earners, or 0.95 per cent of the population.

On the basis of the Eleventh Census (which contained no enumeration of mining or metallurgical engineers) I estimate that there could not have been at that time over 6000 persons in the United States who practiced these professions; and that to keep up the supply would require about 200 new men per year. In the Twelfth Census the mining engineers were enumerated for the first time and the number given is only 2908. Metallurgical engineers are not specified; but under the head of "Chemists, Assayers and Metallurgists" the number is 8887. It is plain that a liberal outside estimate of mining engineers and metallurgists would be ten thousand; and to keep up the supply would take about 330 new men each year. By including assayers, mine-surveyors, and the various minor officials of mining and quarry companies, who might require some technical training, this number might possibly be doubled or even trebled. But when we remember that for many of these positions very little training is required, and that they are open to any one who wishes to attempt the work, including many mining students who fail to graduate, it must be evident that there is a legitimate field for not much over 300 mining-school graduates each year. In 1893 I showed that there already existed in the United States a much larger number of mining schools than was really needed; and the number is now much greater. The attendance at many of these schools has already increased enormously. At the University of California, for instance, the gain has been nearly 1400 per cent since 1887. There is no doubt that the demand for mining engineers in America can easily be supplied by the existing schools. It would be a distinct advantage if they could be restricted to a very much smaller number. Not more than six, or at most a dozen, favorably distributed according to the needs of the mining communities, could do all the work demanded of them much better than a larger number. Under American conditions no regulation but that of natural competition is possible. Much could be gained, however, if the existing schools would coöperate to fix a common standard for the degrees given. While no official relation with the mines is possible, the moral effect of such a step would be very great.

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[1] *Transactions*, XXIII, 444; also, *Transactions* of the Society for the Promotion of Engineering Education, vol. I, 1893.

Degrees

One of the reasons that so little attention has been paid in America to college degrees in the past is the great unevenness of the requirements for them in different parts of the country. Wherever a degree, or its equivalent, has come to mean something definite, as with our military and naval academies, it has received full recognition.

Still, there are indications of a general change in the public estimate of degrees. This has been most marked in regard to the degrees of Doctor of Philosophy and of Science. These have come to mean a capacity for original investigation in some branch of science or letters. It would be a distinct advantage to the mining schools, and to the mining profession, if a similar definite meaning always went with that of the degree of mining engineer.

At present the practice of American mining schools differs greatly in this matter. Some give the degree of mining engineer at the end of a four years' undergraduate course. One even gives it in three years; one has attempted a five years' course, but has unfortunately gone out of existence. Others give, for much the same amount of work, only the degree of Bachelor of Science at the end of the undergraduate course, and reserve the degree of mining engineer for advanced work.

I am convinced that no matter how excellent the course of a mining school, it is a distinct mistake to give the degree of mining engineer on the same basis as that of the bachelor's degree. Some engineering schools, recognizing this difficulty, have attempted to institute as a mark of greater attainment the absurd degree of doctor of engineering.

The highest degree given by a mining school should be that of Mining Engineer. This degree should be put on the same basis as that of Doctor of Philosophy, or of Science. It should be confined to those who have not only mastered the fundamental training, but have shown by actual accomplishment that they possess, in addition, the precious qualities of initiative and capacity as leaders in engineering, and also that maturity of mind and character which one naturally associates with the profession of the engineer. If this standard could be maintained, the degree of Mining Engineer from an American mining school, in spite of its disconnection with Government service, would soon stand higher than that of any other country in the world.

It must be evident that it is not possible to crowd a complete technical education into a four years' course, without neglecting the broad basal training that is necessary for advanced work. But if some such plan as I have outlined were adopted by the leading American mining schools, a great advance would be made.

A large number of men could then take advantage of the undergraduate course which would then, in a new sense, and in a much higher form, take the place of the *Bergschule*. In this school all would receive the fundamental training necessary for the mining engineer, together with some knowledge of the various technical branches. After finishing this course of four years, and receiving the bachelor's degree, the best thing for all to do would be, as a rule, to plunge directly into the realities of the mining life. All could then step at once into the lower ranks of the profession. Most would undoubtedly be contented to remain there, filling a useful place in the general scheme, now occupied by men without either scientific or technical training; thus raising the standard of the entire industry. But the chosen few who possess the creative faculty of the engineer should be encouraged to find their special bent and field as soon as possible, and then to throw their whole strength into a real mastery of the chosen specialty. A man is then in a position to specialize as much as may be necessary without becoming narrow. Three years of mature work along these special lines, in graduate work, either in college, or, under proper conditions, outside of it, should lead to the production of a piece of original work which would justly entitle him to the degree of Mining Engineer.

Such a policy would parallel, without imitating, the methods that have been so successful in encouraging advanced and independent workers in our universities. It would create an American *Bergakademie* that would be superior to anything of the kind in Europe. And it would secure for America, by a process of natural selection, a body of mining engineers worthy of their natural heritage.

SHORT PAPER

Professor James D. Hague, of New York City, presented a paper to this Section on "Mining Engineering and Mining Law."

SECTION E — TECHNICAL CHEMISTRY

SECTION E—TECHNICAL CHEMISTRY

(*Hall* 16, *September* 23, 10 *a. m.*)

CHAIRMAN: DR. H. W. WILEY, U. S. Department of Agriculture.
SPEAKERS: PROFESSOR CHARLES E. MUNROE, George Washington University.
PROFESSOR WILLIAM H. WALKER, Massachusetts Institute of Technology.
SECRETARY: DR. MARCUS BENJAMIN, U. S. National Museum.

THE RELATIONS OF TECHNICAL CHEMISTRY TO OTHER SCIENCES

BY CHARLES EDWARD MUNROE

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As the term technical chemistry is usually used, it refers to the commercial production of substances through a change in the chemical composition of the matter employed in their manufacture. All manufacturing operations are either chemical or physical ones or both chemical and physical. The manufacture is a chemical one when the substance or substances acted upon undergo a change in composition. The manufacture is a physical one when the substance acted upon undergoes a change in form, state, state of aggregation, appearance, or properties without any change in its composition. Many manufacturers, probably the majority, include both chemical and physical processes in their operations. In most manufactures the chemical processes are the basic ones producing the material, which is afterward shaped and assembled by physical means in the form in which it is to be used.

The variety of substances embraced in chemical technology is seen in such a work as Wagner's *Chemical Technology*, but no statistics indicating its magnitude are to be found, except in the reports of the United States Census, this being the only country which takes a census of manufactures. Following the classification of Wagner, I have compiled these statistics for the years 1890 and 1900:

Statistics of Chemical Manufactures in the United States, 1890 *and* 1900.

Year.	Number of establishments.	Number of wage-earners.	Total wages.	Cost of materials used.	Value of products.
1900	84,172	1,038,543	$469,848,022	$3,392,211,974	$4,962,715,787
1890	58,195	710,485	311,369,495	2,177,443,777	3,165,768,188

The term technical chemistry may, however, properly be extended to include the work done by chemists not engaged in manufacturing, but which aims at a utilitarian application of the results. First in order of development among these is the class of chemists engaged in the work of chemically inspecting material from all sources to ascertain its suitability for its proposed uses, or its purity, or its conformity with the specifications under which it was purchased. All economically managed and well conducted operations of any magnitude to-day are subjected to this check. In fact we may say that, since governments by legislation specify the fineness as well as the weights of the gold and silver coins they issue, and since the fineness of these coins as well as of the bullion in the Treasury is constantly proved by analyses, therefore every commercial transaction throughout the civilized world is eventually based upon the results of chemical tests. The historian Du Cange gives the credit for "inventing" assaying to Roger, Bishop of Salisbury, during the reign of Henry I. Be this as it may, it is owing to the accurate analyses of assayers such as Tillet, Stas, Graham, Torrey, Eckfeldt, Roberts-Austen, and their successors that the credit of our metallic currency has been and is maintained. The office of public analyst and assayer, or, as it is often styled, "State Assayer," is of long standing, Charles XI of Sweden having, in 1686,[1] established a technical laboratory for the chemical examination of natural products and the working-out of processes for their practical utilization. The Census of 1900 reports that there were 8847 persons practicing in the United States in that year as chemists, assayers, and metallurgists, and it is gratifying to observe that this class of technical analytical chemists is rapidly increasing in numbers and importance.

Second in the order of development is the work done in the technical research laboratories, where methods are tested and criticised, processes are developed, apparatus and machinery invented, new products discovered, new applications for known products found, and where yields and costs are ascertained. Notable among these are the famous research laboratories of the Badische Anilin und Soda Fabrik, the Welcome Research Laboratories, and many others that may be readily called to mind, and so fruitful and valuable have these establishments proven that similar ones are rapidly being established about manufacturing works. Their success seems also to have suggested the formation of the independent research companies, formed explicitly to combine research with practical application, especially in electro-chemistry, one such located in this country having, among others, developed processes for the manufacture of barium hydroxide, synthetic camphor, and nitric acid from atmospheric nitrogen.

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[1] *History of Chemistry*, E. von Meyer, p. 138.

Of necessity many of the arts preceded the sciences, and this was especially the case in chemistry, as many of the arts embraced in technical chemistry, such as the utilization of fuel as a source of energy, the manufacture of alcoholic beverages, bread, soap, glass, and dyestuffs, the isolation of metals, the expression of oils, and the extraction of sugar, starch, gums, glucosides, and alkaloids, among others, were practiced, in an empirical way, long before the science of chemistry took form. In 1724, after chemistry had emerged from alchemy, Boerhave defined chemistry as "an art which teaches the manner of performing certain physical operations whereby bodies cognizable to the senses or capable of being rendered cognizable or contained in vessels are so changed by means of proper instruments as to produce certain determined effects, and at the same time discover the causes thereof for service in the arts."

The science of chemistry was a growth from the art and gradually developed. It was a crude science when the phlogiston theory was propounded, and many of the advocates of this theory, such as Stahl, Marggraf, Scheele, Bergmann, Priestley, Cavendish, and Black contributed much valuable experimental and observational data from their researches. But it takes date as a recognized science when Lavoisier provided it with a systematic notation and nomenclature, Dalton enunciated his atomic theory, and Berzelius demonstrated the constancy of combining proportions and of constitution, and its growth since the beginning of the nineteenth century has been almost marvelous.

The distinction between pure and applied chemistry was universally recognized toward the middle of the eighteenth century, special text-books on technical chemistry, in which theory was combined with practice, and embracing analytical processes, particularly as they related to ores, being issued. In fact, from the outset technical chemistry has naturally drawn continually upon pure chemistry for products, processes, and apparatus, modifying the processes and apparatus to meet the conditions of factory practice. So rapid, however, has this adoption of the appliances of the university laboratory by the technical chemists become in these recent years, since university-bred chemists have been received in continually increasing numbers in technical chemistry, that it has proved a source of embarrassment to teachers of chemistry in this country and for the following reason:

From the founding of the United States it has been a settled policy of the Government to foster education, and therefore the first Congress, in legislating on the tariff, exempted from duties philosophical apparatus and instruments imported for use in education, and this legislation was reënacted with enlarged provisions in every tariff act passed by Congress, except during the Civil War, and once, in 1846, when it was apparently omitted by inadvertence. This provision seemed to serve all intended purposes until some thirty years ago, partly because there were but few active laboratories for the teaching of chemistry, with a small number of students, and that the supplies were imported for only a part of these laboratories. However, with the increase in research laboratories in universities and technical schools, the introduction of laboratory courses for the large classes of pupils in the secondary schools, and especially the appointment of a considerable number of teachers of chemistry who had been educated abroad, the demand for foreign-made apparatus and supplies became quite considerable, and as the importations grew in magnitude and frequency differences arose between the customs officials and the importers as to whether the goods imported were actually those designated in the act; the customs officials, as was natural, considering their functions, ruling for that interpretation of the laws which would yield the Government the greatest revenue. Controversy, which became quite heated, arose particularly as to the meaning of the terms "philosophical and scientific apparatus, instruments, and preparations," and in 1884 the Secretary of the Treasury, to avoid any appearance of arbitrarily overruling his subordinates, which would have been subversive of discipline, took counsel of the National Academy of Sciences; but its opinion as rendered, while perfectly correct, failed of effect, and the controversies got into the courts on issues between merchants and the customs service in such form as to lead to decisions which the customs officials regarded as supporting their controversies against the schools. Such were the conditions in 1893, when the American Chemical Society appointed a Committee on Duty-Free Importations, which made an exhaustive search into the legislation, an inquiry into the litigation, and a study of the entire situation, until, finding a favorable opportunity in an issue brought before the proper tribunal, it convinced the judges that there were no instruments, apparatus, or preparations which to-day were exclusively used in teaching or research; that, on the contrary, our manufacturers and practitioners are so keen to utilize every resource at command that they are the first usually to test, and if found profitable, to adopt any new invention in apparatus or discovery in preparation, while teachers must usually await the voting of appropriations or gifts from benefactors before they can possess them, and that as no distinction can be drawn either arbitrarily or from the rule of "principal use," we must revert to the "evident intent" of Congress to exempt education from the burden of the tariff, and in each instance the levying of duties or admission of the goods free must be determined solely by the fact as to whether or not they are to be used in the institutions designated by the act for educational purposes and research. It is pleasant to record that the board of appraisers, after thoroughly reviewing the history, adopted this view, and that during the present year Assistant Secretary Armstrong, in charge of the customs service, has promulgated it in a very satisfactory form for the instruction of his subordinates.

This is but one instance of a multitude which may be cited showing how technical chemistry "treads on the heels" of pure chemistry. It depends especially on the votaries of the latter for accurate determinations of chemical constants. Prof. F. W. Clarke has emphasized the importance of this in the case of atomic weights, taking the case of chromium[1] as an example. He says: "The older and less accurate determinations for chromium led to the figure 52.5. The more recent and more accurate have given 52.1 as the number. The European technical analysts, who analyze chromium ores for the sellers, use the first-mentioned number; the chemists for the consumers in this country use the latter number, with the result that the difference in value on a cargo of ore weighing 3500 tons is $367.50."

The technical chemist has been keen to appreciate the necessity for authoritative standards by which his work might be controlled and to which matters in controversy might be referred. He has especially welcomed and willingly assisted in the formation of standard bureaus. In fact, the movement for the creation of a National Bureau of Standards in the United States originated in the Association of Official Agricultural Chemists through Mr. Ewell, and though when, on the motion of this gentleman, the plan was afterwards indorsed by the American Chemical Society, it received the complete approval of the pure chemists, Dr. William McMurtrie and Dr. Charles B. Dudley, who stand in the front rank as technical chemists, were most active in its promotion and successful in convincing our national legislators of the economic advantages which would result from the establishment of such an institution invested by law with the proper authority.

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[1] *Journal of American Chemical Society*, vol. XIX, p. 359, 1897.

Technical chemistry is indebted to pure chemistry for much precise information regarding the properties of substances, especially as to their behavior toward reagents, and for accurate and carefully investigated analytical methods like those with which the honored name of Wolcott Gibbs is associated. But the technical chemist revises these methods and adapts them to his special needs, as shown in the standard work of Blair on the *Chemical Analysis of Iron*, and in others that might be cited, while he verifies the published data as to the particular substances with which he has to deal. Realizing that "time is money," he has devised, with the aid of the collected information, rapid methods of analysis[1] which enable one to arrive at an approximately true and in some instances a very precise result in a few moments, when the academic methods require hours and perhaps days to arrive at the same conclusion. It is true that methods of this nature, devised to meet technical needs, have been generalized and made more available in the university laboratory. As an early example of this we have volumetric analysis, devised by Descroizille and Vaquelin, investigated and generalized by Gay Lussac, and as a recent example we have the use of a rotating electrode in electrolysis, long employed in the arts, critically studied and generalized by Smith, by Gooch, and by their pupils. Yet the systematic treatment of the accumulated material, the working-out of a comprehensive scheme of qualitative analysis, and the collating, the sifting, and the arrangement of correlated methods for quantitative determinations in a connected manner are due to C. Remigius Fresenius, who for so long conducted a technical analytical laboratory at Wiesbaden, and his publications are classics.

But technical chemistry has especially looked to the pure chemist, with leisure for thought and work and with libraries and other facilities at command, to correlate and discuss data, to trace relations, suggest hypotheses, invent theories, and discover laws which the technical chemist has been ready to test and, when proved, to be guided by. To-day we find the technical chemists earnestly studying Arrhenius's theory of electrolytic dissociation, Willard Gibbs's phase-rule, van 't Hoff's law governing osmotic pressure, Guldberg and Waage's law of mass-action, and the many other valuable generalizations which have resulted from the systematic cultivation of the borderland between the sciences of physics and chemistry that has been going on with increasing activity during the past quarter of a century. It is safe to say that the series of text-books of physical chemistry now being edited by Sir William Ramsay, and of which the *Phase Rule and its Application*, by Alex. Findlay, is the pioneer, will find their way largely into the libraries of the technical chemists. Many examples may be cited of the utilization of these generalizations in the solution of problems in technical chemistry, but Christy's[1] admirable researches into the rationale of the cyanide processes for the recovery of gold from its ores will suffice. The experience of the past has repeatedly demonstrated the commercial possibilities that are latent in scientific theories. A famous example is found in the commercial development of benzene. Lachman, in 1898, after referring to its discovery by Faraday in 1825, and its production from benzoic acid by Mitscherlich nine years later, says:[2] "These famous chemists little thought that their limpid oil would once lay claim to be the most important substance in organic chemistry; that it would give birth to untold thousands of compounds; that it would revolutionize science and technology. The technical development of benzene and its derivatives employs over fifteen thousand workmen in Germany alone; the commercial value of the products reaches tens of millions of dollars; by far the greater portion of the research work done to-day is concerned with the same group of substances. Nearly all of this tremendous activity is due to a single idea, advanced in a masterly treatise by August Kekule in the year 1865. Twenty-five years sufficed for the chemists of all nations to recognize the inestimable importance of the benzene theory, for in 1890 they came together at Berlin to do honor to the man who had created a new epoch in the science." There is abundant verification of Hoffmann's statement that "the technologist is not likely to leave long without utilization any fact of science which may be developed and made valuable from the technical side," and of Ostwald's saying "that the science of to-day is the practice of to-morrow."

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[1] The number of determinations made in one week in the laboratory of the Bethlehem Iron Company amounted to 2444; accurate analyses of carbon being made in 12 minutes, of manganese in 10 minutes, and of phosphorus and silicon in 30 minutes. *Engineering & Mining Journal*, LX, 375, 1895.

In his most attractive book, *Physical Chemistry in the Service of the Sciences*, van 't Hoff says: "There exists in Germany a very beneficial coöperation between laboratory work and technical work. Both go as far as possible hand in hand. After physical chemistry had made several important advances and was firmly established in such a way that pure chemistry was assisted by coöperation with it, Ostwald judged correctly that this coöperation would also be valuable in technical directions," and these views led to the founding of what is now the German Bunsen Society for Applied Physical Chemistry, whose considerable membership comprises both men of pure science and representatives of technical science. The suggestions of applications from men such as Ostwald, van 't Hoff, Bancroft, and others, accompanied as they are by striking demonstrations, are always most welcome and appreciated. But it is no new custom for the most eminent exponents of pure science for a while to step into the field of application. We have but to cite the names of Baeyer, Berzelius, Bunsen, Davy, Debus, Dumas, Faraday, Fischer, Frankland, Hoffmann, Liebig, Mabery, Remsen (to whom the medal of the Society of Chemical Industry has just been awarded), Williamson, and Wurtz as examples. Or, taking a single technical subject, such as the explosives industry, we have Lavoisier perfecting the manufacture of gunpowder; Gay Lussac serving on the advisory committee of powders and saltpeter; Berthollet inventing chlorate powders; Liebig investigating the fulminates and devising means by which the commercial manufacture and use of mercuric fulminate was made possible; Schoenbein discovering gun-cotton and introducing it for use as a propellent; Bunsen, with Schischkoff, making researches on the composition of powder gases and powder residues; Berthelot, led by a patriotic desire to serve his country in time of peril, exhaustively experimenting with explosives of every description, collecting and correlating the data of his own experiments with that previously recorded and combining this with the descriptions of the attendant phenomena and the theories he had deduced from analyses of all this material in his *Force of Explosive Substances*, and Mendeléeff and Dewar developing the smokeless powders adopted by the countries of which they respectively are citizens.

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[1] *Transactions*, Am. Inst. Mining Eng., vol. XXVI, p. 735, 1897, and vol. XXX, p. 864, 1901.

[2] *Spirit of Organic Chemistry*, p. 21.

While technical chemistry is under manifold obligations to pure chemistry, the indebtedness does not stand unrequited. I would amplify this branch of my subject but that it has been so admirably done by Dr. William McMurtrie in his address on "The Relations of the Industries to the Advancement of Chemical Science,"[1] in which it is shown that many discoveries which have materially affected pure chemistry have been made in the factories. It is a well-known fact and quite in the nature of things that the pure chemist is dependent upon the technical chemist for most of the material used in his researches, and the publications contain frequent acknowledgments of this fact.

Technical chemistry in common with pure chemistry is under lasting obligations to physics. It makes use of the physical properties of matter for purposes of identification and separation. It employs her instruments, such as the spectroscope, the polariscope, the microscope, the photometer, and a multitude of others, in analytical operations. It utilizes the various manifestations of energy in accordance with the physical laws which govern them, adopting the methods of transformation, conveyance, and application which the physicist has shown to be most efficient, convenient, and safe, though adapting them to the particular circumstances which obtain. It relies upon the physicist for the verification of its standards of mensuration, and, as previously stated, it employs physical, together with chemical, processes in its treatment of material in manufacture. A modern instance of this relation of technical chemistry to physics is found in the electro-chemical industry. Starting with the remarkable experiments of Sir Humphry Davy in 1807, which resulted in the isolation of sodium and potassium, the commercial utilization awaited the discovery of an adequately cheap source of available electrical energy, which was realized on the invention of the dynamo in 1867. When its practicability was demonstrated, and especially after it had been shown that a head of water could be employed as the primary source of this energy, the electro-chemical industry began and achieved such proportions that in the year 1900, in the United States alone, phosphorous, sodium, and other metals, not including aluminium, were isolated, and caustic soda, bleaching powder, and other bleaching agents, bromine and potassium bromide, potassium chlorate, litharge, graphite, calcium carbide, carborundum, and carbon disulphide, amounting in value to $2,045,535, were manufactured by electro-chemical methods. Many other products have been obtained by this means in the laboratory and have been expected in the industry; but while the industry is a growing one it is not growing as rapidly in the variety of its products as some have been led to anticipate. Much depends upon the extent to which low-cost sources of energy are to be commanded, and on this point the following from J. W. Richards's presidential address to the American Electrochemical Society in 1903 is pertinent. He says:

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[1] *Proceedings*, American Association for the Advancement of Science, vol. XLIV pp. 65–85, 1896.

"Niagara Falls is the most accessible of our great water-powers, and has therefore drawn into its fold the majority of our electrochemical industries. But another source of surplus power is distributed over a large part of our country in a condition at present as undeveloped as was Niagara's power when Columbus touched our shores. I refer to the surplus power from blast-furnaces, obtainable by using gas-engines. Every blast-furnace burns its gases to heat its blast and to raise steam for its power. The two thirds of its gases used for the latter purpose generate just about the power needed for the blowing-engines, pumps, hoists, etc., an amount equal on an average to 2500 horse-power for a furnace making 500 tons of iron per day. If the gas thus used was used in gas-engines there would be an average surplus power, over and above all requirements of the furnace itself, of 10,000 horse-power. The gas-engine plant needed to produce this power does not cost over $50 per horse-power investment. This compares favorably with the cost of developing water-powers, which varies from $25 to $100 per horse-power. It is thus deducible that there are scattered over the United States, in some of our most flourishing industrial centres, undeveloped powers which aggregate over 1,000,000 horse-power, which can be developed at no more cost than the average water-power can be generated just at the spots where they can be most favorably utilized, and without any more drain on our natural resources than the harnessing of a new water-power, for not a pound of coal more would have to be burnt than is used at present.

"Other possible sources of power are the waste surplus gases from by-product coking-ovens and the utilization of gas-producers, using cheap, almost waste, coal in connection with gas-engines. Power therefore is available in immense quantities in places and in countries not blessed with Niagaras in their midst, and the industrial development of such sources will be one of the most marked industrial movements of the next ten years."

While recognizing these many obligations to physics, as a *quid pro quo*, technical chemistry supplies her devotees with all the "manufactured" materials which are the subject of their experiments and observations, or used in the construction of their instruments, or as sources of energy — such as coal-gas, acetylene, alcohol, and others, and the substances used for primary and secondary batteries. Many physical topics have originated with or been extended by the technical chemist.

The technical chemist looks to the forester, the farmer, and the miner for his raw materials, but he returns to the former alkaloids, wood alcohol, acetic acid and acetates, acetone, formaldehyde, paints, rubber articles, and a multitude of other products of manufacture; he returns to the farmer starch, sugar, artificial manures with which to reinvigorate his soil, fibers bleached or dyed, the suint from his sheep, the pepsin, pancreatin, and antitoxines from his swine and cattle, and through the agricultural chemist specific directions as to methods for the treatment of his soil and his crops. Since Liebig began the investigations which resulted, in 1840, in his book on *Chemistry in its Application to Agriculture and Physiology*, no one science has probably benefited more from the labors of the technical chemist than agricultural science; for well-equipped research laboratories with well-organized forces of chemists have been devoted by legislation to this purpose to a greater extent than to any other, and the publications from Dr. Wiley's laboratory alone indicate how valuable this has proven to be. As one among many examples, we may cite the sugar industry, which owes its existence to-day in this country, whether the source be sugar-cane or beet, or starch from maize or potato, to the technical chemist.

The technical chemist returns to the miner the metals isolated from his ores in the form of tools and machinery, or coins, or converted into compound substances available as medicines, as disinfectants, as detergents, and for a variety of purposes, and he supplies him with his explosives through which his labor is rendered much less arduous and his life more secure.

The technical chemist looks to the civil engineer to provide the means for the transportation of his raw material and his manufactured products, and to the mechanical engineer for his constructions and his machinery, but he supplies them with all the manufactured materials used in their work, and guarantees by analysis the quality and character of the natural as well as the artificial materials required. So rapid has this method of chemical supervision come into vogue in the last half-century that the engineer, whether he is to build an hotel, a ship, a locomotive, a gun, or a bridge, to lay a concrete foundation, or to surface a road, now introduces into his specifications the chemical requirements which the material must satisfy in order to be accepted for use, and he depends upon explosives to enable him to drive his tunnels, sink his shafts, and remove obstructions from his course. It has excited no particular remark that a chemical laboratory has been established as a part of the preparations essential to the building of a tunnel under the Hudson River.

To the metallurgist technical chemistry has been invaluable, as it has improved the quality, decreased the cost, and increased the speed of production of his materials. The story is an interesting one as we follow it either among the precious or the common metals. As set forth by Bridge in the *Inside History of the Carnegie Steel Company*, where we trace the growth from the Kloman forge of 1853, worth complete, $4800, to the Carnegie Company of 1899, valued at about $500,000,000, the story is a fascinating one in many ways, but in none more than in such rivalries as that between the blast-furnaces started by the Lucy and Isabella furnaces and entered into by the Edgar Thompson, the Carrie, and the Youngstown furnaces, by which the output of pig-iron was increased from 50 tons in each 24 hours to 901 tons in the same period, while the coke consumption per ton of iron was reduced by 50 per cent. No one with sporting blood in his veins but feels a thrill as he follows these records at the blast-furnace, the Bessemer converter, the open-hearth, and the rolling-mill, and especially as he realizes the tremendous issues involved and the enormous amounts of money at stake, and everywhere he finds it is only by the close and constant supervision of the chemist that these results could have been attained while the quality of the product was assured. The authority of the chemist in these enterprises has been extending over a continually widening territory and becoming more positively recognized; so that, taking again the blast-furnace as an example, where at first he was occasionally employed to analyze the ore used or the pig-iron produced, he now analyzes all of the fuel, flux, and ore that goes in at the throat, and the gases, slag, and metal that are produced in the furnace. One has but to examine casually a modern technical work such as Harbord's *Metallurgy of Steel* to be convinced of the absolute dependence of the modern steel-maker upon the technical chemist. Mr. Carnegie admits that he owes his success in steel-making to having been among the first to employ chemists throughout his establishments; and we find that the other industrial combinations, such as the Standard Oil Company, Amalgamated Copper, and the like, which consider no detail of business too small to be ignored, employ chemists at all points, auditing their operations, accounting for their materials at all stages, stopping wastes, diminishing costs, improving the quality and increasing the speed of manufacture.

Technical chemistry, then, invades the domains of economics, of politics, and of diplomacy. A striking example of its effects in economics and politics is found in the settlement of the silver question. Gold is a most widely diffused metal. It has, for instance, been shown by assayers at the U. S. Mint at Philadelphia that if the gold in the clay of the bricks of which the buildings of the Quaker City are built could be brought to the surface, the fronts would all be gilded. In the past our processes for the isolation of this metal have been so costly that only the richer ores would bear treatment. Large bodies of low-grade ores which have been discovered and mountains of tailings carrying values were looked upon as worthless, while enormous quantities of copper, lead, and other metals containing gold were sent into the market to be devoted to common uses, because the cost of separation was greater than the value of the separated products. Eight years ago, when the "silver question" was made the national issue, while the orators were declaiming from the stump, the chemists were quietly working at the problem in their laboratories and factories. Manhé's process for bessemerizing copper ores was combined with the electrolytic refining of the product, so that even traces of gold were economically recovered, while the cyanide processes, such as the MacArthur-Forrest, the Siemens-Halske, the Pelatan-Clerici, and others for the extraction and recovery of gold from low-grade ores and tailings, were successfully worked out and put into practical operation to such effect that by the cyanide processes alone gold to the value of $7,917,129 was recovered in the United States in 1902, which is more than was ever won throughout the whole world by all methods in any one year up to 1661, and probably up to 1701. The data for other processes is not at hand for 1902, but the returns for 1900 show that gold to the value of $88,985,218 was recovered in the treatment of lead and copper ores in the United States, of which $56,566,971 worth was recovered in refining. It has but recently been publicly proclaimed in this city of St. Louis that the "silver question" is settled, and it is settled, but it was settled largely through the efforts of the technical chemist and metallurgist.

Technical chemistry renders important services to medicine in furnishing it with an enormous variety of remedial agents, anesthetics, and other supplies. It is an important factor in the public-health service, supplying disinfectants and deodorizers, inspecting food-supplies, supervising water-supplies, devising methods for the purification of sewage, the treatment of wastes, and the prevention of the pollution of the atmosphere. We have but to mention the names of Pasteur and Pettenkorfer, of Letheby and Wanklyn, and of Drown, Chandler, and Mrs. Richards to emphasize the importance of the chemical factor.

Chemistry is an equally important factor in public safety. A glance at von Schwartz's *Fire and Explosion Risks* will show how varied and extensive but a single one of these fields of activity is. Every one of you as you came here by boat or rail owed a large measure of your safe conveyance to the technical chemist. The regular utilization of these valuable services in this interest is of quite recent date. It was in 1875 that some of the officials of the Pennsylvania Railroad Company, finding that the oil used in their signal-lamps and headlightswas unreliable, and that all empirical methods of examination failed, determined to employ a chemist. Dr. Charles B. Dudley was called, a laboratory was opened at Altoona, and in the face of the skepticism of the "practical" man, the work began and was carried to so successful an issue that a multitude of problems relating to railroad administration have been referred to the chemist, his force of skilled assistants has been steadily increased, and the position of the chemist in the organization is second to none in importance. Other railroad companies, recognizing the gain in economy and efficiency, have also instituted chemical laboratories, until in thirty years it has become common practice. While the Pennsylvania Railroad Company was wrestling with the question of testing oil, the U. S. Light-House Board was having trouble from the same cause, the lamps in the light-houses and beacons along our coast, harbors, and navigable waters having become quite unreliable from the character of the oil furnished, and it, too, sought the aid of the chemist, with such result that it has ever since relied upon chemical science to define and pronounce upon the quality of its supplies.

It has been said that the state of civilization of any country may be determined by the amount of soap which it consumes. Lord Beaconsfield considered that the condition of the chemical trades constituted the best industrial barometer. In his pamphlet on *The American Invasion, or England's Commercial Peril,* when discussing "the best index of a nation's prosperity," B. H. Thwaite says: "Had he [Beaconsfield] selected the iron and steel trades, he would have made a far better choice." I have given these citations from the many at command as illustrating the tribute paid by the thoughtful to technical chemistry. Technical chemistry promotes civilization, profoundly modifies national policies, and influences diplomatic proceedings. The most frequent cause of friction between nations to-day is found in the endeavor of each of the world-powers to control territory for the exploitation of their products or as sources of their raw materials.

Technical chemistry, as practiced in the past from the dawn of manufacture, is a most important subject for consideration by the anthropologist, which has unfortunately been too much neglected. Its study will bring rich yields to the anthropologist who comes to it with the proper preparation, for he will find in the arts embraced in technical chemistry the best gauge of the extent of civilization of a people. Historians agree that no one material thing has more profoundly influenced civilization than gunpowder has. Over fifty years ago, under circumstances somewhat similar to those which obtain here, a body of scholars under the leadership of Dr. Whewell, Master of Trinity College, reviewed the results of the famous exhibition which had just been held in London. I desire to call the attention of the anthropologists to the address there given by Sir Lyon Playfair on the *Chemical Principles Involved in the Manufactures of the Exhibition.*

In the autumn of 1874 I was so fortunate as to be the guest, at his residence in the Smithsonian Institution, of Joseph Henry, its first secretary and executive officer from 1846, and I had the precious privilege of hearing from his lips a most detailed account of the development of the Institution from the time when he was assigned the duty of devising and carrying out the plans by which Smithson's wishes should be realized and the provisions of the legislative act creating the Institution complied with, and particularly of the various obstacles which he had encountered and surmounted in his endeavor to use the fund for "the increase and diffusion of knowledge among men" in the spirit in which Smithson, as Henry understood it, intended it should be used. Naturally my interest in this famous Institution was greatly quickened, and I have watched somewhat more keenly the subsequent career of this Institution, and of the organizations such as the Library of Congress, the U. S. Department of Agriculture, the National Museum, and others created or fostered by it. From the outset, however, I have remarked upon the absence from the Museum of any collection relating to technical chemistry, which is so profoundly connected with the history and development of civilization, and which has undergone itself, in its development, so many changes that its tools and appliances and methods disappear completely from view unless preserved in some such historical collection as those made by the museums. I have endeavored, by suggestion to have this oversight remedied, but have been met by the reply that the present building is overcrowded and its resources overtaxed by the mass of material collected in branches at present cultivated. As now the Museum is starting on a new career of usefulness and a new structure of greatly increased capacity is being built, this seems an opportune time to seek publicly this recognition for industrial chemistry, at least in the anthropological collections, and particularly when, as now, to a greater degree than at any other period, such rapid changes are going on in long established and important industries, such as the sulphuric acid and the alkali industries, that the processes of the last century may become among the lost arts of the next century.

Within the present year the remains of Smithson have been removed from the soil of Italy, in which they so long rested, and been reverently and fittingly interred within the confines of the noble and beneficent institution that he founded. The revival of personal interest in Smithson which this removal has aroused has led to the suggestion that a monument be erected to his memory. The Smithsonian Institution is itself an enduring monument; but if another be created could it not, considering that Smithson was a chemist, fittingly take the form of a chemical collection in the Museum which so long benefited by his bequest.

SOME PRESENT PROBLEMS IN TECHNICAL CHEMISTRY

BY WILLIAM HULTZ WALKER

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TECHNICAL chemistry may be regarded as the performance of a chemical reaction or series of reactions on a scale sufficiently large and by a method sufficiently economical to enable the product to be sold at a profit. The problems which confront the investigators in this field of endeavor may, therefore, be divided into two classes, according as they pertain to the chemical reaction involved or to the process to be employed in carrying on this reaction. The first division is pure chemistry, even though the results of the solution be utilitarian; the second is chemical engineering. Although in the Programme of this Congress, the utilitarian side of chemistry is widely separated from the subject of general chemistry, there is in reality no dividing-line between the two. It would be difficult to find an investigator in the field of pure science who does not hope, and indeed believe, that the results of his labor will at some time prove of value to humanity; may ultimately be utilitarian. On the other hand, few, if any, chemical manufacturers would admit that in solving their chemical problems they do not utilize the most scientific methods at their command. The research assistant is in the last analysis utilitarian; while the successful chemical engineer is preëminently scientific.

Probably in no country have the problems confronting the chemical industries been so successfully met as in Germany; yet Germany does not excel in chemical engineers. Engineering enterprises, mechanical, civil, and electrical, as well as chemical, are carried on as successfully in England and America as they are in Germany, and still the latter leads the world in her chemical manufacturers. The explanation for this lies in the fact that Germany pays the greatest attention to the first class of problems, as above divided, and recognizes that pure chemistry is inseparably connected with her industries; that the application of new facts and principles follow rapidly when once these facts and principles are known. Most of her problems in technical chemistry are first considered as problems in pure chemistry and studied in accordance with recognized methods of modern research by men fully trained in pure science. If these men are also chemical engineers the ultimate solution of the problem is proportionately hastened; but they are first of all men trained in the spirit and methods of scientific research.

In general, an investigation may be prompted by either or both of two incentives; either by the pleasure to be derived from achievement and the love of scientific study for itself, or by the hope that from the investigation some immediately useful result may be obtained. Yet between the product of the first motive — pure chemistry — and the ultimate result of the second — technical chemistry — a difference does not necessarily exist. The fact that a piece of work is undertaken and carried on with the predetermined purpose of applying the results to a practical or commercial end does not in itself render it any the less a study in pure chemistry. The method of thought and action employed will be that of the investigator in pure science, whatever the ultimate object may be. To make the result of the work an achievement in technical chemistry an important contribution must then be made by the chemical engineer, in order that the conditions forming the definitions of the term "technical chemistry" as already stated may be fulfilled. In trying to point out some of the important problems in technical chemistry, no attempt will be made to distinguish between the part which must first be played by pure chemistry in their solution, and that which will still remain to be done by the chemical engineer to make this contribution utilitarian.

There is always a tendency to measure the importance of a subject by the extent of one's knowledge of it and the depth of the interest one has in it. In order, therefore, that we may obtain a proper perspective, we must consider a problem important in proportion as it affects the greatest number of people; of moment according as the results of its solution will be far-reaching in their effects, or be but of local benefit.

From this point of view the first industry to demand attention is the manufacture of fertilizers. In the last ten years the product of this industry in the United States alone has increased from 1,900,000 tons to 2,900,000 tons, an increase of over fifty per cent. This increase is probably more marked in America than in the older countries of Europe, because the necessity of replenishing the virgin soil was there reached long ago, while with us it is only begun. The magnitude of the industries which are dependent directly or indirectly upon agricultural products is so well recognized that it needs no discussion here. That the supply of crude material from which plant-life derives its nourishment should be maintained is therefore a source of responsibility for the present, as well as for future generations. Of this, as of every great industry it may be said that the supply of raw material for to-morrow is a problem for to-day.

Dr. H. W. Wiley, of the United States Department of Agriculture, has pointed out the surprisingly large amount of potash, phosphoric acid, and nitrogen which is yearly taken up by the agricultural crops alone. The average percentage of ash in all of the important crops has been accurately determined and their percentage composition in respect to potash and phosphoric acid is known. In addition to this we have a satisfactory knowledge of the percentage of albuminous matter contained in the more important agricultural products. From these figures and the reports of the United States Department of Agriculture we can calculate the amount of potash, phosphoric acid, and nitrogen consumed each year. Allowing a value of 4 cents a pound for potash, 5 cents for phosphoric acid, and 12 cents for nitrogen, the total value of these ingredients for a single year amounts to the enormous sum of $3,200,000,000. To be sure this is not all removed from the farm and lost to the soil; but that which remains in the form of straw and manure is but a small percentage of the whole. Straw is generally burned, while the soluble salts of the manure-heaps are often allowed to leach out and go to waste. When in addition we consider the terrible waste involved in the modern methods of sewage disposals where, instead of being returned to the soil, these valuable constituents are carried to the ocean, the net loss of these chemicals can be easily appreciated.

Of these three most important ingredients making up a fertilizer for general purposes, phosphoric acid alone seems to be at hand in practically inexhaustible quantities. Slag, rich in phosphoric acid from certain metallurgical processes, is already much used as a source of the material. Fresh deposits of phosphate rock of such enormous extent are being brought to light almost every day that our supply of this material may give us little immediate concern.

Although the Strassfurt region of Germany may continue to ship undiminished quantities of potash salts, the second important ingredient of a fertilizer, the world's supply cannot be said to be on a perfectly satisfactory basis until independent sources are developed. In the year 1902 the value of the potash salts imported into the United States amounted to $4,500,000. The recovery of potash from wood ashes, while once an important industry, must diminish as the value of hard wood increases. While there are doubtless natural beds of potassium salt still to be discovered, the time seems rapidly approaching when we should render more readily available the great amount of potassium distributed throughout the mineral kingdom. Rhodin had already accomplished much toward this end when he showed that feldspar could be made to yield the greater part of its potash when it was heated with lime and common salt. Clark has found that when the mineral leucite, with its 21 per cent potassium oxide is heated with ammonium chloride, the potassium is converted into chloride and is easily separated from the melt. If this reaction could be extended to orthoclase and the ammonia recovered by treatment with lime, the enormous quantity of potash contained in this mineral would be at our service.

It is, however, to the supply of available nitrogen that the greatest importance attaches. The sodium nitrate producing countries of South America exported last year 1,300,000 tons, a large percentage of which came to America. Egypt and the Southwestern United States have nitrate deposits, but of their extent and value little is as yet known. Of the other form of available nitrogen, ammonia, our main supply is at present from the destructive distillation of coal. Although the introduction of by-product coke-ovens has increased this supply, our domestic production is now not over 40,000 tons a year.

In the atmosphere, however, we have a never-failing source of nitrogen which needs only to be converted into other forms to be of the greatest value. It is interesting to note that even as long ago as 1840 this same problem was the subject of considerable experimentation and the basis of several technical processes. In this year there was erected in France a plant for the manufacture of potassium ferro-cyanide, which depended on the atmosphere for the supply of nitrogen, and which at one time turned out almost a ton of product per day. From this time until the present, the utilization of this inexpensive and inexhaustible supply of raw material has been an attractive field, and has held the attention of many investigators. It had long been known that while carbon and nitrogen alone could not be made to unite, the union was effected when these elements were brought together in the presence of a strong alkali. The technical difficulties in the way of successfully applying this reaction seem to have been the rapid destruction of the retorts and the loss of alkali through volatilization. With the advent of cheap electricity and the consequent development of the electric furnace, this idea was made the basis of further work. The destruction of the retorts was largely overcome by generating the heat within the apparatus rather than without. When a non-volatile alkali was used to eliminate the loss from this source and a higher temperature maintained, it was found that a carbide was formed as an intermediate product and that nitrogen readily reacted with the carbon thus held in combination.

Among the investigators who have thus far taken advantage of this reaction may be mentioned the Ampere Chemical Company located at Niagara Falls, and the group of men represented by the Siemens-Halske Company of Berlin. The former first produces a carbide of barium and then converts it into barium-cyanide by passing over it air from which the oxygen has either been removed or converted into carbon monoxide. Robert Bunsen long ago showed that by using steam the nitrogen in all alkaline cyanide may be converted into ammonia. In this case barium oxide would be left to be returned to the furnace, and to continue the cycle. When advantage is taken of the process discovered by Professor Ostwald, by which ammonia is converted into nitric acid through the medium of a catalyzing or contact agent, the production of nitrates by way of the cyanide reaction is easily foreseen.

The Siemens-Halske Company prepared, in addition to cyanide and ammonia, by use of the carbide-nitrogen reaction, a new compound in technical chemistry, calcium cyanamide. In contradistinction to the cyanides the nitrogen of this compound is available for plant-food and can take the place of the more common nitrogen salts in commercial fertilizers. The technical difficulties in the way of the economic application of these processes are doubtless very great, but when one considers the advance which has been made in the last five years he has ample reasons to believe that it will not be a great while before the synthetic preparation of the cyanides, ammonia, and nitric acid from atmospheric nitrogen will be on a commercial basis.

The old reaction by which nitrogen and oxygen were made to unite through the agency of a high potential electric discharge has been made the basis of a process for the manufacture of nitric acid by the Atmospheric Products Company, operating at Niagara Falls. For agricultural purposes it is proposed to absorb the nitric acid thus formed in milk of lime, and so produce an exceptionally cheap product. There still remains much to be done before this can be called a technical process.

A very much less technical, but, so far as our knowledge at present goes, a more promising method of fixing atmospheric nitrogen in the form of nitrates is through the agency of bacteria. While it is true that one group of bacteria has the power of breaking down nitrates with the production of nitrogen gas, there are other groups which are equally able to absorb elementary nitrogen with the production of nitrates. A great deal of excellent work has recently been done by the United States Department of Agriculture with the result that cultures for the artificial inoculation of the soil may now be obtained in considerable quantity. It has been found that these bacteria when grown upon nitrogen free media may be dried without losing their high activity. When immersed in water they are easily revived. A dry culture similar to a yeast-cake, and of about the same size, can thus be sent out and used to prepare a fluid in which the original nitrogen-fixing bacteria may be multiplied sufficiently to inoculate a number of acres of land. The amount of material thus obtained is limited only by the quantity of the nutrient water-solution used in increasing the germs. Field experiments have shown the wonderful activity of these bacteria in fixing atmospheric nitrogen and the splendid crops which may be grown upon what would otherwise be almost sterile soil.

In this one problem of our future supply of available nitrogen for agriculture as well as general manufacturing purposes, we note the aid which technical chemistry draws from the other departments of natural science. The electrical engineer and biologist have already contributed a great share in its solution. There remains, however, no small amount of work for the technical chemist to perform before the desired end is reached.

In an address on "Chemical Problems of To-day," delivered by Victor Meyer in 1889, the author pointed out that, although the synthesis of starch from carbon dioxide and water was a result not to be expected in the near future, yet, he says, "we may reasonably hope that chemistry will teach us to make the fiber of wood the source of human food." While we do not consider that this is a problem of technical chemistry for the present, the possible use of cellulose as a raw material from which to make food, renders more acute a problem which is to-day clamoring for solution, namely, the preservation of our forests. The influence which the forests of a country have upon its civilization is a topic which has been much discussed of late. That there is an intimate relation between the woodland of a district and the regularity of its rainfall, the absence of floods and freshets, and the general climatic conditions, there seems now to be little doubt. But the consumption of forest products continues to increase far out of proportion to the growth of new timber. The substitution of other raw material in chemical industries which now use wood for this purpose becomes, therefore, an economic problem for the solution of which the chemist is held responsible.

The production of cellulose from raw materials other than wood is the first important factor in the chemical side of the question. The weight of wood consumed for the production of chemical fiber for the year 1902 was something over two million tons, while one and a half million tons were used for the manufacture of ground wood-pulp. While from some points of view our American forests are sufficient to supply the demand for many years to come, it does not excuse us for the terrible waste of cellulose in forms other than wood, which we are constantly suffering.

On our flax-fields of the West we are annually burning thousands of tons of flax-straw which contains a large percentage of cellulose in a most valuable form. Considerable work has already been done on the utilization of this straw in the production of fiber, and some success has met the efforts of the By-Products Paper Company, now located at Niagara Falls. There is, however, still much room for improvements. In the straw of our wheat and oat crops, which is to-day largely destroyed on the fields, we have another source of cellulose of which we avail ourselves but little. In Europe the production of straw fiber is carried on to some extent, but is capable of great extension should sufficient economy in the process for treating it be introduced. The high content of silica has ever been a source of loss, owing to the fact that the formation of sodium silicate prevents the recovery of the soda now used in the digestion of the straw.

By far the greatest loss of valuable cellulose, however, is found in waste cornstalks and in bagasse or the sugar-cane after the soluble portions have been removed. There is a close analogy between these two products, in that there is associated with the woody portion carrying the cellulose a large amount of non-usable pith. Rapid progress has been made in the utilization of both of these raw materials within the last few years, and the indications are that before long they will prove a source of value rather than a nuisance, as is frequently the case at present. The market price of bleached cellulose fiber is to-day from 2½ to 3½ cents per pound. Starch may be bought for from 2½ to 4 cents, according to its source. It is seen, therefore, that there is little manufacturing margin in the conversion of cellulose to starch or sugar until the cost of the former has been considerably reduced. This can come about only through new processes designed to operate more economically than those at present in use, and to use as raw products the cellulose at present wasted on the fields.

It would seem that a more economical step toward the production of food from wood might be through its ligneous or non-cellulose constituents. For every ton of cellulose produced there must be used two tons of wood; that is, an equal weight is wasted. In the soda process, as now conducted, these non-cellulose materials are burned to recover the soda which is held in combination with them. In the sulphite process this enormous amount of material, aggregating for America alone in a single year almost one million tons, finds its way into the water-courses and ultimately to the ocean. This organic matter is most complex in its composition, but consists largely of one class of substances closely allied to the sugars, and another class having the general characteristics of tannins. That these sugar-like substances could be made to yield a food material is, from their nature, quite possible; so far as we know, however, but little has been accomplished in this direction. A number of uses have from time to time been proposed for this waste, but as yet none have been of practical value. Among the more promising may be mentioned a preparation to be used in tanning leather, a sizing material for paper, and a substitute for dextrine in calico printing, and as an adhesive.

In addition to our annual supply of 4,000,000 tons of paper stock, we depend upon the forests for our supply of acetic acid, methyl alcohol, and acetone. In countries where there is not the exorbitant tax upon fermented mash that exists in the United States, there would seem to be an opening for a process for the production of acetic acid from alcohol in a more concentrated form than can be produced through the aid of *mycoderma aceti*. It would, it is true, in the end depend upon the supply of fermentative material; but there are being wasted every year in the semi-tropical countries many thousand tons of crude molasses that could thus serve an economic end. For many uses acetic acid may be displaced by formic acid, a compound which admits of synthesis from carbon and water. The farther this substitution is carried the more acetic acid will be available for the manufacture of acetone and other compounds where the acetyl group is a necessity.

Concurrent with the disappearing forests is the increasing scarcity of vegetable tanning material. Hemlock and oak bark, sumac and chestnut wood are still the most important sources of tannins, although quebracho from South America and canaigre from Mexico and Texas are daily playing a more important part. The introduction of chrome tannage for upper leathers had a marked influence upon this industry, inasmuch as it furnished a cheap substitute for those finer tanning materials which are constantly increasing in price. A mineral tannage for heavy hides, along the lines so successfully followed for upper leather, has, however, not been developed; the product lacks the rigidity and firmness combined with the flexibility which is characteristic of oak or hemlock tanned leather. There must exist methods for supplying to the hide materials having an action analogous to these vegetable tannins; it remains but to seek them out in order that a new and profitable industry may be established.

It is thus seen that technical chemistry can do much for the conservation of our forests; along many lines the time for action has already come.

When the consumption of a given article is in excess of its supply, the market price must rise. In accordance with this law we have seen the price of crude India rubber more than double in the last few years. The consumer of the finished article must pay this advance or accept an inferior grade of goods. Generally he does both.

The tropical forests of Africa and South America still contain untold quantities of India rubber; but so does sea-water contain gold.

For manufacturing purposes both might as well not exist. The only human beings that can live under the conditions obtaining in these tropical jungles are the natives; but the distance to which the natives can transport the rubber is comparatively limited. Although rubber-bearing trees are now being cultivated in the more easily inhabitable portion of the tropics, it will be a long time before this source of supply is an important factor in the market. And thus it comes that the synthesis of India rubber presents to-day from at least the technical side, one of the most promising problems in chemistry.

The investigation of India rubber is greatly handicapped by the fact that it exists only in the colloidal state. The difficulties are perhaps more largely physical than chemical; that is, it is the molecular aggregation rather than the atomic structure of the individual molecule which presents such almost insurmountable difficulties. There are no clearly defined melting-points, boiling-points, tendencies to crystallize or any of those means of separating mixtures or characterizing individuals which aid in the investigation of most organic compounds. The researches of Weber and Harries, resulting in the establishment of the much-needed methods of analyses, have been of incalculable advantage to all those working with either the raw or the manufactured article. In many directions also, the paths along which important results are to be obtained have already been blazed by these investigators. Probably no other field presents such difficulties of manipulation, in addition to such profound problems of organic chemistry, as does the investigation of India rubber; but on the other hand, few such unlimited opportunities for valuable work are offered in the field of chemical research.

Under the general head of utilization of trade-wastes may be considered a large number of technical problems, the solution of which would not only add wonderfully to the economic resources of the country, but would aid in the solution of that much vexed question, river-pollution. We have already mentioned the soda and sulphite liquor resulting from the manufacture of cellulose fiber from wood. Of almost equal importance is the waste yeast which is daily produced in the brewing of beer and ale. An extract of this yeast has a food value, as shown by analysis, equal to the best meat extracts. As the quantity of yeast allowed to go to waste is from one to two pounds for every barrel of beer brewed, we can form estimates of the great amount of this material at hand. Arsenic sulphide from the purification of crude acids, grease from the washing of wool, the utilization of city garbage and many other problems of this order are everywhere in evidence. It is not within the compass of this discussion to mention these almost innumerable sources of manufacturing waste which exist in the chemical industry; but keen competition on the one hand, and the State Boards of Health on the other, are constant stimuli to increased effort toward their utilization.

Although I have endeavored to select the above examples of unsolved problems with a view to touching upon as large a portion of the field of technical chemistry as possible, I could doubtless, with equal propriety, have selected others. We can simply mention such important questions as the hygienic preservation of food, the flameproofing and preservation of wood, prevention of the corrosion of structural iron and steel, the great problems of chemical metallurgy, etc. We must, however, note some of the more recently developed forces and phenomena of nature, the application of which to technical chemistry forms problems for to-day. One of the most important of these is electricity. Thanks to the triumphs of modern electrical engineering we are now able to call to our aid unlimited amounts of this agent at a cost comparable to that of other forms of energy. Possibly the simplest, though not the earliest method of utilizing electrical energy in chemical processes is in supplying the heat necessary to carry on a reaction directly at the point where the reaction takes place. In a number of chemical industries (for example, the manufacture of phosphorus) it was previously necessary to produce within thick-walled retorts a very high temperature. The result was that a great deal of heat was wasted, the retorts deteriorated very rapidly, and the reaction was carried on at a low efficiency. By using an electric furnace for the manufacture of phosphorus these expensive retorts are eliminated. In addition much cheaper raw materials may be used, the process is made continuous, and a high efficiency obtained. By the substitution of electrical heating for the closed retorts previously used in the preparation of carbon bisulphide the manufacture of this chemical has been placed upon an entirely new basis. The economy introduced by supplying the heat at the point where the union of carbon and sulphur takes place is clearly indicated by the low price at which this material can now be sold and its enormously increased consumption.

With the ability to obtain temperatures far above that which is possible by the ordinary combustion of fuel, there was opened up a new field in synthetic chemistry. Reactions which it was impossible to carry out on a technical scale, and others, the existence of which was not suspected, have now, through the application of electrical energy, become the bases of large manufacturng enterprises. Calcium carbide, carborundum, artificial graphite, and many hitherto unknown alloys are the commercial products of the electric furnace where temperatures in the neighborhood of 3000° C. obtain.

The third and more strictly chemical application of electrical energy is in the use of the current for electrolysis. Faraday long ago determined the laws according to which chemical compounds break up when subjected to the passage of an electric current. It is only in recent years, however, that the cost of electrical energy has made it possible to apply the knowledge thus furnished by this great investigator. Among the many important advances due to this use of electricity may be mentioned the manufacture of caustic soda and bleaching powder by the electrolysis of brine. The percentage of the world's supply of these two standard articles, which is now made by this process is already a formidable figure, and constantly increasing. In the electrolytic production of aluminium we have seen an entirely new industry develop, until it is now one of magnificent proportions.

What the application of electricity will do for technical chemistry in the future can be predicted only by estimating the results of the past. In many fields it is practically virgin soil over which only the pioneers have trod, and which is still waiting to be tilled.

Under the name of catalysis or contact action is included the other force that we can mention this afternoon, the usefulness of which the technical chemist is only beginning to appreciate.

These substances which are capable of so wonderfully increasing or decreasing the speed of a reaction without themselves appearing in its final products vary in their nature from such simple ones as metallic platinum or ferric oxide to the most delicately constituted ferments or enzymes. The manufacture of concentrated sulphuric acid by such a process is perhaps the most striking example of the application of this idea, although, to be sure, the finely divided platinum used at present plays but the rôle which the oxides of nitrogen have done so successfully in the past. The reproduction of photographic negatives by substituting for the action of light on sensitized paper the contact action of certain chemical compounds, is a process worthy of its distinguished discoverer, Professor Ostwald. For this application of catalysis even the most pessimistic must prophesy a great future. Still another phase of this question is found in the hydrolysis of fats by the enzyme found in the seeds of the castor-oil plant. Instead of the application of acid, heat, and pressure the same result is obtained at room temperature by the quiet action of this catalytic body. The advantages to be reaped by the development of these phenomena can scarcely be foreseen. Even the wildest dreamer might easily do injustice to the possibilities of this wonderful agent when intelligently used by the technical chemist.

We probably should not invite criticism were we to state that wherever we find a manufacturing establishment based upon chemical processes, there also exist problems in technical chemistry. That one factor which is so apparent that it scarcely needs mentioning, namely, the increase in the yield of processes now in operation, is enough to substantiate this assertion. The paramount question before us is therefore how can these problems best be solved. In any answer to this question there are two factors both of which deeply affect the future growth of chemical industry. The first is the attitude of the manufacturer towards science and scientific work; the second is the training of the coming chemist.

When a few years ago England awakened to the fact that many industries in which she was the pioneer and at one time the leader were in the main passing to other countries, there went up a great cry for "technical education." The nature of the industrial stimulus which has borne such magnificent fruit in Germany was not understood. In the minds of many a panacea for all their difficulties was to be found in the technical education of the working classes. But this is unquestionably a mistake. Until there is a love of science for its own sake and an appreciation of the value of scientific method among the leaders of chemical industry, the fruits of technical education cannot be reaped. Carl Otto Weber, speaking of this move toward a more general scientific education in England, says: "Until the nation, as a whole, recognizes that the prosecution of scientific study as a mere means of money-making is a profanation defeating its own end, the history of industrial developments in England will afford the same melancholy spectacle in this as in the last century, technical education notwithstanding."

The time is past when a factory can be run by rule of thumb; when the chemist is looked down upon simply as a testing-machine to be kept at a distance and generally mistrusted. It is true that there are many men to-day who pass under the name of chemists who are little more than testing-machines; men who possess the ability to do nothing more than the most strictly routine analysis; but such men will never solve the technical problems of the present or any other time. I would not impugn the dignity or intrinsic value of analytical work — it is the corner-stone of all chemical investigation. But I would emphasize the fact, for it is a fact, that the manufacturer who employs a so-called chemist, one trained to "do" coppers or carbons, or acids, and who at the same time expects this chemist to improve his process and keep his business in the skirmish-line of the industrial battle, must eventually be numbered among the "not accounted for."

The second factor in this answer is the training of the coming chemist. What is the reply to that now so oft-repeated question: What is the best preparation for a technical chemist? I am personally of the opinion that it is not to be found in the teaching of applied chemistry as this term is generally understood. This training must provide for something more than simply copying the present — doing as well as others do; it must build for the future. We must provide men who are prepared to solve the unsolved problems. Within the last few months much has been said and written in America about the lack of adequate instruction in technical chemistry in our universities and colleges. It is assumed that American industries, based on chemical processes, do not flourish for lack of men trained in this branch of science. This, however, is not the case. It is not more instruction in applied chemistry that America needs, but rather a deeper and broader knowledge of pure chemistry with a more extended training in original research.

In many of the problems we have already noticed, the solution depends upon the discovery of new compounds — the investigation and study of new reactions and relationships. This is the province of pure organic and inorganic chemistry. The foundations of these two departments cannot be too firmly or too broadly laid. The method of attack best followed in each cannot be too well understood. But it is not sufficient that we study only the initial and the final products. It is all important to learn the influence of the variable factors on the process; to study the reaction for itself. This is the province of physical chemistry, a department of science, the importance of which to technical chemistry cannot be overestimated. To be able actually to apply the laws of chemistry and to predict the course of reactions from general principles already proven is a tremendous economy of both time and energy.

After we have acquired the tools, however, we must learn to use them; after we possess a sound knowledge of inorganic, organic, and physical chemistry we must have adequate training in work requiring original and independent thought.

As I have already noted, the training to be derived from an investigation may be the same even though the incentive for its undertaking may be different. While I believe that so far as possible the student should be influenced to work for the love of knowledge and for the mastery of science for itself, yet especially in his later years of study there are advantages in allowing him to combine with this a utilitarian aim. In America, at least, most men enter our technical schools with the intention of fitting themselves as rapidly as possible for some useful calling in life. They have a feverish desire to get through and to enter the creative industries and accomplish something. They will work with enthusiasm upon whatever they can be made to recognize as contributing to this end, but by their very directness are intolerant of supposed digressions from their chosen path. The presence of too much of this spirit is to be regretted; but it is a power to be turned to service, not to be opposed. It does not follow that for a training in scientific method and for broadening the mental horizon a research which can have little, if any, practical value is superior to one, the solution of which can find immediate application. For advanced work, as much pure organic chemistry, for example, can be learned from an attempt to convert safrol into eugenol (a consummation in itself devoutly to be wished) as in the transformation of some other compound with a much longer name but with no higher destiny than to fill a place in Beilstein. So also in physical chemistry. A careful, painstaking investigation of some of our already established industrial processes with a view to determining the maximum yield at the minimum cost is of the greatest educational value. In other words, a problem for research may have a distinctly practical bearing without being any the less a study in pure science, or without having thereby an inferior educational value.

In other problems, we have noted, the solution largely depends upon the process, not the reaction. This demands the chemical engineer, a man who combines a broad knowledge of chemistry with the essentials of mechanical engineering. He must be well schooled in the economics of chemistry; have a knowledge of the strength and chemical resistance of materials; be able to design and operate the mechanical means for carrying out on a commercial scale the reactions discovered, and duplicating the conditions already determined.

All this training cannot be combined in the one man who takes a four years college course. Either he must study an additional year or two, or he must replace some of his chemical work with mechanical engineering. But such a man must contribute a great share in the ultimate success of chemical industries, for on him depends the solution of the problems comprising the second division of our subject.

With men whose foundations are thus broadly and deeply laid, anxious to enter the industrial arena, and with a generous appreciation of the scientific man on the part of the manufacturer, coupled with a willingness to grant him an adequate return on the money invested in such an education, the problems in technical chemistry of the present must rapidly become the achievements of the past.

SHORT PAPERS

Dr. Samuel P. Sadtler, of Philadelphia, Pennsylvania, read a paper before this Section on "Flameless Wood," and discussed the various processes of fireproof treatment.

The following paper on "The Relation of Technical Chemistry to Human Progress" was presented by Dr. Harvey W. Wiley, of the United States Department of Agriculture, and Chairman of the Section of Technical Chemistry:

I yield to no one in my admiration for that part of our science which is perhaps sometimes improperly denominated "Pure Chemistry." To be sure, we need not object to the use of the word "pure" as applied to chemistry, and it seems to me it can be applied to all branches with equal propriety. The term "pure" as used above, however, refers solely to chemistry when considered entirely apart from any practical application or general utility. And yet it is almost impossible to consider chemistry in that light. No matter how abstract the investigation may be as a rule it treats in some way of human interests. In other words it is quite impossible — it seems to me — to divorce chemistry from the humanities. Technical chemistry perhaps more than any other branch of our science lies quite close to human hopes and human progress. The application of chemical investigations forms the foundation of sanitation and hygiene. It provides the remedies which are used in diseases. It produces antitoxins which counteract biological poisons, and builds up the technique which renders their manufacture and distribution possible. It determines the purity of the water-supply and of the air. It discovers the forms of food adulteration which are injurious to health and presides over the inspection which prevents them, and in a dozen other ways ministers to the public health. It is evident that technical chemistry in this aspect tends to prolong human life and make it more useful. After all, life is the one great desire of man and thus in prolonging it technical chemistry ministers to man's supreme desire more than any other branch of chemistry or of any other science. Technical chemistry opens the wilderness to civilization. By its means have been built those marvelous lines of communication between distant parts of the same country and countries separated by the seas. The railway and all its appliances are creatures of technical chemistry. The steamship is no less so. Thus technical chemistry is the most important of the sciences lying at the basis of transportation. Associated with its sister science, "Physics," chemistry has helped to build up the great industry of the applications of electricity to the arts. Electro-chemistry is intimately associated with all that the mastery of electrical science has done for human progress. It may not be much to its credit, but chemistry is the dominant science in the art of war. It not only makes the explosives but also the guns which carry them, and while it is true that chemistry has thus made war more deadly, it has without doubt made it more humane. The fierce personal hatred and enmity which must have characterized the hand-to-hand fighting of antiquity is now an incident rather than the whole of battle. No sooner, however, has technical chemistry made as efficient as possible the implements of destruction than it turns, on the other hand, to ameliorating the suffering of the wounded and thus softens the pangs of the hospital and saves thousands of lives which otherwise would have succumbed to wounds. There is perhaps no more remarkable contrast than these two applications of technical chemistry, on the one hand to destroy and on the other to save. In the art of agriculture, technical chemistry is one of the chief factors, and agriculture must be recognized as the basic industry of all that relates to the welfare of man. We might get along without the facilities of transportation, we might do away with the adaptations of the electrical force to industry, we might dispense with the perfected armaments of modern battleships, but we cannot do without food and clothing, and these scientific agriculture furnish. While almost every science contributes something to agriculture, and while we recognize the contributions of all fully, we must admit that chemistry takes the lead. Chemistry determines the fertility of the soil, the character of the materials removed by the crop, and furnishes the means to restore the plant-foods which are removed. It studies the processes of nutrition and shows how foods can be used to secure the best economical results. It improves the yield of old fields by the scientific application of fertilizers combined with systematic mechanical treatment. It adapts the raw material of agriculture to specific uses. It develops great industries which without it would be forever dormant, as, for instance, the beet-sugar industry, which is, it may be said, almost purely a chemical product. In fact the applications of chemistry to agriculture are so numerous and important that only a volume could adequately portray them. If, therefore, it be adjudged proper to call abstract chemistry pure, we must claim that it is only appropriate that technical chemistry should be called perfect.

After all, man is the chief thing to be valued in this world and all that ministers to his welfare, to his progress, and to his happiness should receive the special favor of human thought. That application or effort which does not do something for the advancement of man — directly or indirectly — is hardly to be thought worthy of occupying the time of man. We, therefore, deem it only fitting that the authorities in charge of the Programme of this Congress should have made a special division of this, in some respects, the most important part of our science.

DR. MARCUS BENJAMIN, of the United States National Museum, and Secretary of the Section of Technical Chemistry, presented the following valuable paper on "The Historical Development of Technical Chemistry in the United States:"

The inventive genius of the American people is universally conceded. The necessity of accomplishing things quickly, incidental to the growth of a new country, such as ours, has naturally led to the invention of many forms of labor-saving machinery, and so with improved appliances have come improved methods. The technical chemist is, however, less fortunate than his brother in the professorial chair whose merits are made known by his students, thus attracting an ever-increasing following to his laboratory, and perhaps he is also less fortunate than his associate who devotes himself to research work; for to him are given medals and honorary memberships, which are properly the "blue ribbons" of science; hence it is that the discoveries of the technical chemist, especially where they are commercially meritorious, remain too frequently unknown, and the profits of the improvement go to swell the dividends of the corporation to which he owes his allegiance while he receives no public recognition. It naturally follows, therefore, that any summary of the achievements in the development of technical chemistry must be very incomplete.

To say when chemistry begins is not generally possible, for its origin wanders back into alchemy and pharmacy on the one side and into physics on the other, and there are no sharp lines of separation among the various branches of science, for they gradually merge one into the other. In this country, however, we have grown to accept the date of the arrival of Joseph Priestley, June 4, 1794, as a most excellent time at which to begin the modern history of chemistry.

The younger Silliman's masterly *American Contributions to Chemistry*[1] gives me the right, therefore, to mention first Benjamin Thompson, Count Rumford

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[1] *American Chemist*, 1874, vol. v, p. 70.

(1751–1814),[1] whose studies in heat and fuel were as practical as they were important. His early knowledge of science was acquired from John Winthrop (1717–1779), who held the chair of mathematics and natural philosophy at Harvard from 1738 till his death. Of Count Rumford I have said elsewhere:[2] "He investigated the properties and management of heat, and the amount of it that was produced by the combustion of different kinds of fuel, by means of a calorimeter of his own invention." By reconstructing the fireplace he so improved the methods of warming apartments and cooking food that a saving of fuel of almost one half was effected. He improved the construction of stoves, cooking-ranges, coal-grates, and chimneys, and showed that the non-conducting power of cloth is due to the air that is inclosed in its fibers. Silliman well says of him: "No writer of his time has left a nobler record of original power in physical science than Rumford." It will also be remembered that by will he provided funds "to teach by regular courses of academical and public lectures, accompanied by proper experiments, the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness, and well-being of society."[3] Let me also remind you that Wolcott Gibbs, the oldest and now the Nestor of American chemists, held the Rumford chair in the Lawrence Scientific School of Harvard from 1863 till 1888, during which time many of those who are now leaders in chemistry were students under him.

The last century was only a year old when Robert Hare (1781–1858) communicated his discovery of the oxyhydrogen blowpipe to the Chemical Society of Philadelphia. This instrument held a foremost place for the production of artificial heat until the recent introduction of the electric furnace. The application of the principle invented by Hare still finds extensive use for lighthouse illumination and similar purposes under the names of "Drumond light" and "calcium light." It is interesting to recall in this connection that Hare was the first to receive the Rumford medals from the Academy of Arts and Sciences.

Hare was also the inventor in 1816 of a calorimotor, a form of battery by which a large amount of heat was generated, and four years later he modified this apparatus, with which, then known as Hare's deflagrator, in 1823 he first demonstrated the volatilization and fusion of carbon. His memoir on the *Explosiveness of Niter*, which was published by the Smithsonian Institution in 1850, was one of the earliest contributions by an American to the literature of explosives.[4]

The original discovery of chloroform is clearly of American origin and must be credited to Samuel Guthrie (1782–1848), of Sacketts Harbor, New York, whose researches anticipated those of Soubeiran, Liebig, and Dumas by nearly a year. A committee of the Medico-chirurgical Society of Edinburgh gave him the credit for having first published an account of the therapeutic effects of chloroform as a diffusive stimulant. Dr. Guthrie was likewise the inventor of a process for the rapid conversion of potato starch into sugar. He also experimented with considerable boldness in the domain of explosives, inventing various fulminating compounds, which he developed commercially.[5]

Among early technical chemists Samuel Luther Dana[6] (1795–1868) stands deservedly high. His friend, Dr. A. A. Hayes, has testified to "his great fertility in original devices for general and technological work." While chemist to the Merrimac Manufacturing Company of Lowell, Massachusetts, he undertook systematic researches on the action of the dung of beeves — then used for removing the excess of mordant in printing calicoes with madder — which resulted in the discovery that crude phosphates in a bath with bran are a complete substitute for the expensive material before deemed indispensable. This important discovery led the way to the commercial employment of "dung substitutes." His studies of the chemical changes involved in the process of bleaching cotton brought about the universal adoption of the methods recommended and resulted in the recognition of the American method of bleaching which, according to the French chemist Persez, "realizes the perfection of chemical operations."

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[1] See *Memoir of Sir Benjamin Thompson, Count Rumford, with Notices of his Daughter*, by George E. Ellis; also *Complete Works of Count Rumford*, 4 vols. published by the American Academy of Arts and Sciences (Boston, 1876).

[2] *Cyclopædia of American Biography*, vol. v, p. 345, article Rumford, Benjamin Thompson, Count.

[3] *American Chemist*, vol. v, 1874, p. 73.

[4] *Smithsonian Miscellaneous Collections*, vol. II, 1895. Also see the memoir of him by the elder Silliman in the *American Journal of Science* (2), XXVI, 1858, p. 100.

[5] An account of his career has been published in pamphlet form by his descendant, Ossian Guthrie.

[6] See sketch of Samuel Luther Dana in *Pioneers of Science in America* (New York, 1896), pp. 311–318.

It would be an ungracious task to discuss in this paper the much-controverted "ether discussion," but I may say, without fear of doing injustice to any of the several claimants for the honor of the discovery of this important anesthetic, that Charles Thomas Jackson (1805–1880), said to be one of the foremost chemists of his time in this country, claimed, from experiments made by himself during the winter of 1841–42 in his own laboratory, that he obtained results showing "that a surgical operation could be performed on the patient under the full influence of sulphuric ether without giving him any pain." Four years later (in 1846) this was successfully accomplished by Dr. William T. G. Morton, who had studied chemistry in Dr. Jackson's laboratory. The French Academy of Sciences decreed one of the Montyon prizes to Jackson for his discovery of etherization and one to Morton for his application of that discovery to surgical operations.[1]

Metallurgy is little more than the application of chemical knowledge to the extraction of metals from their ores, and I, therefore, beg to claim for the United States the first commercial production of steel. Zerah Colburn, the well-known engineer, gives William Kelly (1811–1888), an ironmaster of the Suwannee furnaces of Lyon County, Kentucky, the credit for the "first experiments in the conversion of melted cast-iron into malleable steel by blowing air in jets through the mass in fusion." Later, when Sir Henry Bessemer made efforts to secure the patent of the process that bears his name, it was decided by the United States Patent Office that William Kelly was the first inventor and entitled to the patent, which was promptly issued to him. In 1871, when application was made for a renewal of the patents originally issued to Bessemer, Mushet, and Kelly, the last was successful, while the claims of the first were rejected.[2]

The successful electro-deposition of nickel and its commercial development are chiefly due to the energy of Isaac Adams, a resident of Cambridge, Massachusetts. He carefully studied the subject and found that the failure to obtain satisfactory results was caused by the presence of nitrates in the nickel solutions previously used. His invention gave rise to prolonged litigation, but in the end he was victorious. Dr. Chandler thus describes it in the following words: "The novel proposition was presented to the court, of a patent for not doing something, namely, for not permitting nitrates to find their way into the nickel solutions employed in nickel-plating, and the court held that the exclusion of nitrates was an essential condition of successful nickel-plating, and that a process involving this condition was just as patentable as a process involving any other special condition necessary for successful execution, and the patent was sustained."[1]

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[1] Dr. Jackson published a *Manual of Etherization, with the History of this Discovery* (Boston, 1861), and much interesting information is to be had from a "Report of the House of Representatives of the United States of America, vindicating the rights of Charles T. Jackson on the Discovery of the Anesthetic Effect of Ether Vapor." The other side of the controversy is given in *The Discovery of Modern Anesthetics: By whom was it made?* by Laird W. Nevius, New York, 1894.

[2] Much has been written of the claims of Kelly, and nearly all of the leading American metallurgists agree in conceding his priority. Swank and various writers in the *Transactions* of the American Institute of Mining Engineers may be consulted. Kelly's own story, as he gave it to the present writer, appears in the *Iron Age*, February 23, 1888, p. 339.

In passing I may mention the name of Joseph Wharton (1826–), whose experiments in producing nickel in a pure and malleable condition so that it could be worked like iron, culminated in the first production, in 1865, of malleable nickel.

Chemistry owes a great debt of gratitude to the genius of Thomas Sterry Hunt (1826–1892), and one of his most notable contributions to technology is the permanent green ink which he invented in 1859 and which is used in the printing of our national bank-notes and from the appearance of which the well-known term of "greenback" was derived. The Hunt and Douglas process for the precipitation of copper by iron, for a time so extensively used for the extraction of copper from low-grade ores, is an invention the credit of which he shares with the well-known metallurgist, James Douglas.

The vulcanization of India rubber by sulphur is the invention of Charles Goodyear (1800–60), who was so persistent in his efforts as to become an object of ridicule. Indeed, he was called an India rubber maniac and was described as a "man with an India rubber coat on, India rubber shoes, and in his pocket an India rubber purse, and not a cent in it." His invention consisted in mixing with the rubber a small quantity of sulphur, fashioning the articles from the plastic material, and curing or vulcanizing the mixture by exposure to the temperature of 265–270° F.[2]

Of almost equal importance was the invention of hard rubber or vulcanite, for which Nelson Goodyear (1811–57), a brother of Charles Goodyear, obtained a patent in 1851, claiming that the hard, stiff, inflexible compound could be best obtained by heating a mixture of rubber, sulphur, magnesia, etc., but this never became an article of commerce. In 1858 Austin Goodyear Day (1824–89) patented a mixture of two parts of rubber and one of sulphur, which, when heated to 275–300° F., yielded the flexible and elastic product now generally known as hard rubber.[3]

Dr. Leander Bishop has said: "In the art of modifying the curious native properties of caoutchouc and gutta-percha, and of molding their plastic elements into a thousand forms of beauty and utility, whether hard or soft, smooth or corrugated, rigid or elastic, American ingenuity and patient experiment have never been excelled."[4]

Exceedingly valuable to the industries of this country was the influence of James Curtis Booth (1810–88), who from 1849 till his death was melter and refiner in the United States Mint. In 1836 he established a laboratory in Philadelphia for instruction in chemical analysis and chemistry applied to the arts, and in the course of a few years gathered around him nearly forty students, among whom were Martin H. Boyé, John F. Frazer, Thomas H. Garrett, Richard C. McCulloh and Campbell and Clarence Morfit, all of whom have achieved eminence as chemists. It was said of him "that Mr. Booth had few, if any, superiors as a teacher of practical chemistry." From 1836 till 1845 he held the chair of chemistry applied to the arts in the Franklin Institute, delivering three courses of lectures extending over three years each. He was the author of an *Encyclopedia of Chemistry* (Philadelphia, 1850) and with Campbell Morfit of a report *On Recent Improvements in the Chemical Arts*, published by the Smithsonian Institution in 1852. His appointment to the mint was coincident with the discovery of gold in California, and the new processes required to prepare the bullion for coinage were largely of his own invention and many of them, to use his own words, "were not known outside the mint."[1]

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[1] *Journal of the Society of Chemical Industry*, vol. XIX, p. 611, 1900.

[2] His life has been published by Bradford K. Peirce with the title, *Trials of the Inventor*, New York, 1860.

[3] *American Chemist*, vol. II, p. 330, 1872.

[4] *A History of American Manufactures*, by J. Leander Bishop (Philadelphia, 1860).

It is well known that prior to 1850 and for some time thereafter Philadelphia was the acknowledged centre for the manufacture of chemicals for medicinal use. To collect the details of the many improved methods for the production of these chemicals would be a long and difficult task, and would require more space than I have at my command in this article. The names of such firms as Powers and Weightman and Rosengarten and Sons are readily recognized as those of manufacturers of standard chemicals. M. I. Wilbert has recently published a paper entitled *Early Chemical Manufacturers: A Contribution to the History and Rise of the Development of Chemical Industries in America*, to which I must refer you for further information concerning their growth and progress.[2]

I am reminded in this connection that the name of Edward Robinson Squibb (1819–1900) is one well worthy of deserved recognition among manufacturers of chemicals. The ether prepared by him by processes of his own invention has long been accepted as standard. For a brief period during the early fifties of the last century Dr. Squibb was associated with J. Lawrence Smith (1818–83) in Louisville, Kentucky, in the commercial production of chemical reagents and of the rarer pharmaceutical preparations.[3] It is also proper to add the name of the Baker and Adamson Chemical Company of Easton, Pennsylvania, as that of a corporation which has established a reputation for the manufacture of pure chemicals by processes, many of which are of their own devising. The success of this young firm is generally admitted to be largely due to Edward Hart[4] (1854–), who fills the chair of chemistry in Lafayette College.

Eben Norton Horsford (1818–93) made distinct contributions to technical chemistry and among these may be mentioned his invention of condensed milk. According to Charles L. Jackson, he originally prepared that most valuable article of food for use in Dr. Kane's Arctic expedition and afterwards presented the process to one of his assistants, who then sold it to Gail Borden. His name, however, is more commonly associated with his invention of a phosphatic yeast powder, the object of which is to return to the bread the phosphates lost in bolting the flour, and which, as is well known, form such an essential constituent of the food of animals. He also devised "a marvelously compact and light marching

[1] A sketch of his career by Patterson Du Bois was presented before the American Philosophical Society on October 5, 1888, and has since been issued in a pamphlet of eight pages.

[2] *Journal of the Franklin Institute*, vol. CLVII, p. 365, 1904.

[3] See *Original Researches in Mineralogy and Chemistry*, by J. Lawrence Smith (Louisville, Kentucky, 1884), p. xxxviii.

[4] Since this address was written I have learned that credit is due to Professor Hart for a complete process for the manufacture of nitric acid from Chili saltpeter, by means of which it is possible to distill the acid continuously and to make it of any strength and any degree of purity. This process is not only used by the Baker and Adamson Company but also by a number of powder concerns both in this country and abroad. Professor Hart is also the inventor of a complete process for the manufacture of hydrochloric acid which is being used in Easton. One of his earliest patents was for the manufacture of a pure hydrofluoric acid which he put on the market in a container, for which he received the John Scott legacy medal and premium of the Franklin Institute in Philadelphia.

ration of compressed beef and parched wheat-grits," which found some use at the time of the Civil War, and his name is also attached to the preparation of "acid phosphate," so commonly used with summer beverages.[1]

The development of the mineral resources of our country has been due largely to those who from their knowledge of chemistry were able to recognize the commercial value of the natural deposits in the vicinity of their homes. This has been conspicuously the case with the great fertilizer industry of the South, and especially so in South Carolina, where the names of Charles Upham Shepard (1804–86) and St. Julien Ravenel (1819–82) are recognized as those of pioneers in that important branch of chemical industry.

To quote from Silliman again, and he is always an acceptable authority, "No observation or original research of Dr. Shepard has been fruitful of so much good in its consequences as his discovery of the deposits of phosphate of lime in the Eocene marl of South Carolina and the distinct recognition of its great value for agriculture." [2] It was Dr. Ravenel, however, whose experiments made it possible to transform these phosphate rocks into commercial fertilizers, and of him the younger Shepard wrote in 1882: "Well might this community erect a public monument in honor of the man to whom preëminently is due the inauguration of that phosphate industry which has proven of such incalculable value to ourselves and others. As the statue of Berzelius adorns beautiful Stockholm, let us commemorate [similarly] the founder of Charleston's greatest industry." It may be added that Dr. Ravenel differed from the agricultural chemists of his time in devoting greater attention to the physiological phases of the application of fertilizers to plants than to the mere chemistry of the subject; this was naturally due to his early training in medicine.[3]

It would lead me too far from chemistry, perhaps, to discuss the work of the younger Shepard (1842–) in successfully introducing tea culture into the United States, but his farm in Summerville, South Carolina, is a monument to the application of his chemical knowledge to a new industry, and well may his fellow countrymen be proud of the results.

It is desirable to mention at this place the remarkable successes achieved by a small band of chemists who spent the four years of our Civil War in their southland. George Washington Raines (1817–98), John Le Conte (1818–91), Joseph Le Conte (1823–91), and John William Mallett (1832–) are among the more conspicuous names that occur to me. It was Raines who erected at Augusta, Georgia, the Confederate powder-works, which at the close of the war were regarded "as among the best in the world."[4]

The Confederate Government appointed John Le Conte to the superintendency of the extensive niter-works established in Columbia, South Carolina, which place he retained during the war.[5] Joseph Le Conte, a younger brother, served as chemist to the Confederate laboratory for the manufacture of medicines in 1862–63, and also in a similar capacity to the niter and mining bureau in 1864–65. Professor Mallett was in charge of the ordnance bureau of the Confederate States, serving with the rank of colonel. He has described his experience under the title *Applied Chemistry in the South during the Civil War*,[1] which he has delivered as a lecture before various chemical societies.

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[1] A sketch of his career prepared by Charles L. Jackson appeared in the *Proceedings* of the American Academy of Arts and Science, vol. XXVIII, p. 34, 1903.

[2] *American Chemist*, vol. v, p. 96, 1874.

[3] Two memorial pamphlets of Dr. Ravenel have been published. One, entitled *In Memoriam, St. Julien Ravenel, M.D.* (9 pp.), is a reprint of an editorial from the Charleston *News and Courier* of March 18, 1882. The other, entitled *Dr. St. Julien Ravenel*, is a memorial published by the Agricultural Society of South Carolina, Charleston (54 pp.).

[4] He published in pamphlet form a *History of the Confederate Powder Works* (Augusta, 1882).

[5] *Biographical Memoirs*, National Academy of Sciences, vol. III, p. 369.

A history of the manufacture of explosives in this country would carry us far into the past, for the oldest of the still existing powder-mills was established in 1802 by Eleuthére Irene Du Pont and the name of Du Pont is still honorably associated with the industry, for so recently as 1893 two of that name received a patent for a smokeless powder which is now largely made at works near Wilmington, Delaware.

During the years 1862–64, Robert Ogden Doremus (1824–1906) developed the use of compressed granulated gunpowder, which was adopted by the French Government. It was concerning this inventor that Sir Frederick A. Abel in 1890, in his retiring address before the British Association, said that Doremus "had proposed the employment in heavy guns of charges consisting of large pellets in prismatic form." Charles Edward Munroe (1848–) must be recognized as the first in the world to prepare "a smokeless powder that consisted of a single substance in a state of chemical purity." This explosive, which he invented while chemist at the United States Torpedo Station, Rhode Island, and which became known as the "naval smokeless powder," was referred to by Secretary of War Tracy, in 1892, as presenting "results considerably in advance of those hitherto obtained in foreign countries."[2]

Of later development is the Bernadou powder invented by John Baptiste Bernadou (1858–), of the United States Navy, and which it is claimed has been adopted for use in the naval branch of the service.

No contribution to the history of technical chemistry in the United States would be complete without some reference to the development of coal-oil and petroleum. It seems almost impossible to realize that scarcely half a century ago the only use of petroleum was as a cure for rheumatism under the name of Seneca oil. The commercial exploitation of this important illuminant is, of course, largely due to the Standard Oil Company, and to the expert chemists in their employ credit should be given for the production of the many beautiful by-products that are now made. A full description of these, with proper reference to the chemist to whom we are indebted for them, would, indeed, be valuable, but even for a simple enumeration of the products in tabular form giving their immediate origin I must refer you to the text-books on industrial chemistry.[3]

One of the most interesting of these many compounds is vaseline, whose use in pharmacy is so prevalent. It was invented in 1870 by Robert Augustus Chesborough (1837–). Charles Frederick Mabery (1850–) has been an indefatigable worker in the theoretical branch of the subject, especially on the composition of petroleum, in the study of which he has been aided with grants from the C. M. Warren Fund for Chemical Research of the American Academy of Arts and Sciences. Stephen Farnam Peckham (1839–) has been a prolific contributor to the literature of the technology of the subject, and his report on petroleum, prepared for the Tenth Census (Washington, 1880), is standard authority. Another chemist who has studied petroleum both in the laboratory and from a commercial point of view as well is Samuel Philip Sadtler (1847–). His *Industrial*

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[1] An abstract of this paper, with the title *Industrial Chemistry in the South during the Civil War*, is contained in the *Scientific American* for July 25, 1903.

[2] The history of the *Development of Smokeless Powders* was the subject of Dr. Munroe's presidential address before the Washington Section of the American Chemical Society in 1896. See *Journal of the American Chemical Society*, vol. XVIII, p. 819, 1896.

[3] See *A Handbook of Industrial Chemistry*, by Samuel P. Sadtler (Philadelphia, 1900), p. 21.

Organic Chemistry (Philadelphia, 1900) gives a very satisfactory survey of the subject with an admirable bibliography. Among the younger men I learn that William Cathcart Day (1857–1905) has succeeded by carrying out operations of distillation at the ordinary atmospheric pressure upon animal and vegetable matter, both separately and mixed, in obtaining three different materials, all of which present in different degrees the properties characteristic of asphalts.[1]

An early worker in the scientific part of this subject was Cyrus More Warren (1824–91), whose original researches on the volatile hydrocarbons and similar bodies resulted in many practical applications in the use of coal-tar and asphalt, especially for roofing and paving purposes. Clifford Richardson (1856–) has in recent years devoted much attention to the study of asphalt and is a recognized authority on its value for commercial purposes.

I cannot claim for the United States the invention of illuminating gas, although as early as 1823 its manufacture was begun in New York City, but the development of the production of a luminous water-gas was largely accomplished in this country. According to excellent authority,[2] Thaddeus S. C. Lowe (1832–) built and successfully conducted gas-works in Phœnixville, Pennsylvania, in 1874, producing a water-gas "far superior to that made from coal." According to Dr. Chandler "there are forty or fifty differing forms of apparatus for manufacturing [water-gas], but they are almost without exception applications of the invention of Thaddeus Lowe."[3]

Those of us whose memories extend back for a quarter of a century may recall Tessie de Motay (1819–80), whose agreeable personality charmed all of those who were so fortunate as to meet him, and to him is due the production of water-gas in the late seventies of the last century by a process of his own invention in New York City.[4]

A much-needed substitute for ivory and horn that could be produced economically was invented in 1869 by John Wesley Hyatt (1837–) and called by him celluloid. It is so seldom that foreign recognition is unqualifiedly given to our American inventors that I am glad of the opportunity to quote Thorpe,[5] who says, concerning celluloid, that it "is an intimate mixture of pyroxylin (guncotton or collodion) with camphor, first made by Hyatt of Newark, U. S., and obtained by adding the pyroxylin to melted camphor . . . and evaporating to dryness." Its many applications in various industries are so well known as to need no further mention here.

It should not be forgotten that saccharin, a coal-tar compound with a sweetening power of about five hundred times that of cane-sugar, although now manufactured chiefly in Germany, was discovered in 1879 in the laboratory of the Johns Hopkins University by Constantin Fahlberg, a student under Ira Remsen (1846–) and the Society of Chemical Industry in 1904 crowned Remsen's work by conferring upon him the medal of the society, recognizing thus for the first time in its history the discoveries of an American chemist.

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[1] *Journal of the Franklin Institute*, September, 1899, p. 205.

[2] See a *Communication on the Lowe Gas Process*, New York (May, 1876), and *A Communication on the Lowe and Strong Gas Processes* of later date (probably 1878), and also *The Chemistry of Gas-Lighting*, by C. F. Chandler (Philadelphia, 1876), a reprint from the *American Chemist* for January and February, 1876. There is also a pamphlet report on the *History and Value of Water-Gas Processes* (New York, 1864), by John Torrey and Carl Schultz, which gives a brief summary of some sixty patents on the subject.

[3] *Journal of the Society of Chemical Industry*, vol. xix, p. 613, 1900, where also excellent descriptions of both the Lowe and the Motay processes are to be found.

[4] See sketch of Cyprien M. Tessie de Motay by A. J. Rossi in the *Journal of American Chemical Society*, vol. ii, p. 305, 1880.

[5] *Dictionary of Applied Chemistry*, vol. i, p. 449, 1891.

In the domain of technical chemistry no American has ever achieved greater results than Hamilton Young Castner (1858–99), and the opportunity of presenting a brief summary of his brilliant inventions is a pleasure that I gladly welcome. His first invention was a continuous process for the manufacture of bone charcoal, but this failed of commercial success, although scientifically of much interest, and he then turned his attention to the study of an improved method for the production of aluminium. To accomplish this it was necessary to produce sodium economically, and this he succeeded in doing by using carbide of iron as a reducing agent. When he began this now historic research the market price of aluminium was $10 a pound, and when his process was completed he was able to manufacture aluminium at about one dollar a pound. "This," says Dr. Chandler, "revolutionized the whole industry and aluminium could be now used for a hundred different purposes." In his retiring address before the British Association in 1890, Sir Frederick A. Abel said: "The success which has culminated in the admirable Castner process constitutes one of the most interesting of recent illustrations of the progress made in technical chemistry."

But there were other uses for which sodium could be employed, and so he invented a process for converting metallic sodium into sodium peroxide. Then came the suggestion that with cheap sodium pure cyanides could be produced, and so he modified his process so as to manufacture pure cyanides, especially the potassium and sodium cyanides, enormous quantities of which were used for the extraction of gold from low-grade ores. His active mind was ever busy with new solutions of chemical problems, and subsequent to the invention of electrolytic processes for the reduction of aluminium, Castner concentrated his attention on the original methods used by Sir Humphry Davy, and overcoming the difficulties encountered by that great chemist he soon devised an electric process of remarkable simplicity for obtaining metallic sodium from caustic soda by electrolysis. His ambition was not yet satisfied and he added to his triumphs a beautiful method for the electrolysis of common salt [1] with the production of caustic soda and bleaching powder. Thus Castner invented "the first process which could be said to be a complete success for accomplishing what French, German, English, and American chemists had been working at for a hundred years." Again to quote Chandler: [2] "He never worked on a chemical process that he did not invent a better one to accomplish the same result."

The silver metal and the white crystals, pure and beautiful, the results of his many hours of study and research, will always preserve in the literature of chemistry the memory of him of whom it is surely not too much to say that he was the most eminent of American inventors in chemical technology in recent times.

While Castner was studying the problem of preparing aluminium by chemical methods Charles Martin Hall (1863–), a student in Oberlin College, conceived the plan of extracting aluminium by electrolysis and he found that a melted bath of the double fluorides of aluminium and metals more electro-positive than aluminium, such as sodium or calcium, was a perfect solvent for aluminia, and from such a solution he was able to separate the aluminium by means of the electric current. It is by this process that all of the aluminium of commerce is produced to-day.

Moissan, whose extended researches with the electric furnace have made his name justly famous, writes: "The discovery of crystalline carbon silicide belongs to Acheson."[1] This remarkable abrasive, prepared by heating a mixture of silica, coke, aluminia, and sodium chloride in an electric furnace, was invented in 1890 by Edward Goodrich Acheson (1856–) while experimenting for the artificial production of diamonds, and is one of the many beautiful products obtained at Niagara Falls, where quite a number of chemical manufacturers have established their plants in order to take advantage of the power obtained from the great waterfall. Mr. Acheson has also succeeded in preparing artificial graphite as a by-product in the manufacture of the carborundum, and he claims that it is the result of the decomposition of the carbide formed in that process.[2]

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[1] Charles J. Parsons (*Journal of the American Chemical Society*, vol. xx, p. 868, 1898) gives Ernest A. Le Sueur credit for "the distinction of having invented the first electrolytic process for the commercial decomposition of sodium chloride, which became a regular contributor to the markets of the world."

[2] See the *Unveiling of a Bronze Tablet in Havemeyer Hall to the Memory of Hamilton Young Castner*, December 16, 1902, *School of Mines Quarterly*, vol. xxv, p. 204, January, 1904.

Although the existence of calcium carbide has been recognized ever since its original production in 1857 by Edmund Davy, Wöhler, and Berthelot, it was not until May, 1892, that its commercial production became known in consequence of its chance discovery by Thomas Leopold Willson (1860–) while experimenting in Spray, North Carolina. He obtained it by the fusion and reduction in an electric furnace of a mixture of finely powdered and intimately mixed lime and coke. When it comes in contact with water, decomposition ensues, with the production of acetylene gas, an illuminant of remarkable power. This valuable compound is also manufactured at Niagara Falls.

Another valuable application of the high temperatures obtained by the electric furnace to substances from which the extraction of the metal was formerly considered impossible is the method patented in November, 1903, by Frank Jerome Tone (1868–), of Niagara Falls, New York, for obtaining metallic silicon by reducing silica with carbon in an electric furnace of his own construction.

Of great value is the elaborate bulletin[3] on *Chemicals and Allied Products* prepared for the Twelfth Census by Charles Edward Munroe, already mentioned, and Thomas Marean Chatard (1848–). The industries discussed are grouped into nineteen classes and with each the discussion is introduced by a history of the development of the manufacture in the United States, and at the close is a brief bibliography. The volume includes a digest of United States patents relating to the chemical industries.

Worthy of the most distinguished consideration is the career of Charles Frederick Chandler (1836–). This eminent chemist has since 1864 taught the technical chemistry in the Schools of Science in Columbia University and no record of the development of chemistry applied to the arts in the United States would be complete without mention of his work. It is true that no great invention bears his name, but he has achieved results greater than inventions, for he has educated chemists, and yet even more than that as we shall see. Go where you will and you will find busy workers in science who have learned from Chandler something of that splendid power of applying chemical methods to the subject at hand which has long since gained for him the reputation of being the foremost authority on technical chemistry in the United States. Wherever gold or silver is determined, the little assay ton weights — their conception was a stroke of genius — claim him as their inventor. The brilliant series of articles on technical chemistry — the

[1] *The Electric Furnace* (Easton, 1904), p. 273.

[2] *Journal of the Society of Chemical Industry*, vol. XIX, p. 609, 1900.

[3] *Census Bulletin*, no. 210, 4to, 306 pp. Washington, June 25, 1902.

Much credit is due to H. M. Pierce for the process originally invented by him in 1876 and since greatly improved for the recovery of by-products from the smoke of charcoal kilns. See Munroe, *Census Bulletin*, no. 210, and *The Economical Production of Charcoal for Blast-Furnace Purposes*, by O. N. Landreth, *Proceedings* of the American Association for the Advancement of Science, vol. XXVII, pp. 145–151, 1888.

According to Munroe (*Census Bulletin*, no. 210, p. 26) the Pennsylvania Salt Manufacturing Company of Natrona, Pennsylvania, "were the first to manufacture porous alum."

best in the English language — that appeared in Johnson's Cyclopedia were written by him. The first museum of applied chemistry in the United States where the crude material may be studied in its course of development to a finished product was established by him. Masterly, indeed, were the practical contributions to chemistry which marked the years during which he had charge of the public health in New York City. They resulted in enormous benefits to the community, and in 1883 it was well said: "There is no other city in the world which has so complete a sanitary organization as New York;" for all of which credit is due to Chandler.[1] In 1889 he was chosen president of the Society of Chemical Industry, the first American upon whom that honor was conferred, and a year later, on June 18, 1900, in the lecture theatre of the Royal Institution founded by Count Rumford, to whom reference has already been made, he delivered his presidential address on "Chemistry in America," in the course of which he elaborated most fully the achievements of those who have distinguished themselves in that branch of science in the United States.[2]

It is worth while, I think, to mention very briefly three branches of our national government that have had much to do with the development of chemical technology in this country. The first of these and also the oldest, for it celebrated its centenary in 1891, is the patent office,[3] where inventors receive the protection of the government for their discoveries. By thus recognizing worthy inventions a valuable stimulus is given to invention which has not been without value to the community. Of exceptional interest to chemists is the system of indexing chemical literature now in use in the classification division of the patent office.[4]

I will also call your attention to the excellent work done in the Division of Mineral Resources in the U. S. Geological Survey, where under the efficient direction of David Talbot Day (1859–) valuable information and statistics are gathered concerning native minerals and ores from which are obtained the products of so many of the leading chemical processes.[5]

Finally the bureau of chemistry of the Department of Agriculture has been a potent factor in the development of chemical industries. It was that bureau that first called the attention of the public to the possibility of establishing the beet sugar industry in the United States. As a result of the investigations carried on by chemists in this branch of the government service the average yield of cane-sugar to the ton in the state of Louisiana has been increased from 130 pounds to 170 pounds. In the examination of road materials important contributions to technical chemistry have been made by this bureau. The valuable studies on the dietetic value of foods and on their adulterations, conducted under the direction of Dr. Harvey Washington Wiley (1847–), have not only done much towards creating a demand for the enactment of national legislation for pure food, but they have also been praiseworthy contributions to the application of chemistry to sanitation. This bureau also should receive recognition for its fostering influence over the Association of Official Agricultural Chemists, an organization which has done so much to secure uniform methods of analysis of fertilizers and of foods.

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[1] See the sketch of Charles Frederick Chandler by the present writer in the *Scientific American*, vol. LXVII, July 16, 1887, p. 39, and *President Chandler and the New York City Health Department*, 1866–1883, in the *Sanitary Engineer*, May 17, 1883.

[2] *Journal of Society of Chemical Industry*, vol. XIX, p. 591, 1900.

[3] *Patent Centennial Celebration*, 1891: *Proceedings and Addresses*, 554 pp. (Washington, 1892).

[4] See *On a System of Indexing Chemical Literature; Adopted by the Classification Division of the United States Patent Office*, by E. C. Hill, *Journal of the American Chemical Society*, vol. XXII, pp. 478–498, 1900; also *Scientific American*, vol. LXXXVI, June 14, 1902, p. 411.

[5] Beginning with the year 1882, annual volumes of the Mineral Resources of the United States have been published.

To Henry Carrington Bolton (1843–1903) is due the credit for the series of bibliographies of the literature of the chemical elements that have been published by the Smithsonian Institution. His own memory will always be worthily preserved by the splendid *Bibliography of Chemistry* in four octavo volumes, an important section of each of which is devoted to technical chemistry.

The records of the past give abundant hope for the future.

SECTION F — AGRICULTURE

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(*Hall* 10, *September* 24, 3 *p. m.*)

CHAIRMAN: PROFESSOR H. J. WHEELER, Rhode Island Agricultural College.
SPEAKERS: PRESIDENT CHARLES W. DABNEY, University of Cincinnati.
PROFESSOR LIBERTY H. BAILEY, Cornell University.
SECRETARY: PROFESSOR WILLIAM HILL, University of Chicago.

THE RELATIONS OF AGRICULTURE TO OTHER SCIENCES

BY CHARLES WILLIAM DABNEY

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THE subject assigned me is Agriculture in Relation to Science. For this subject, almost cosmical in its vastness, I offer no apology, but ask your indulgence while I attempt to point out a few of the achievements of the new agriculture and to show their relation to the advancement of civilization. While the progress has consisted partly in opening up such lands as are not highly cultivated to people who can cultivate them, its chief progress has been in the improvement of man's methods of cultivating the soil and of using plants and animals to support his ever-increasing numbers. Since population is increasing rapidly and more food is required each year to support the life of the people born into the world, unless the production of food becomes greater in proportion to the unit man and the unit acre, starvation awaits the race. In 1899 Sir William Crookes argued seriously, before a meeting of the British Association, that the world's wheat-supply is already threatened by the failing fertility of the available soil. As the low average of less than thirteen bushels per acre means starvation for the rapidly increasing population of wheat-eaters, when he found the limit of available wheat-lands nearly reached, he saw no hope for the race except by increasing the fertility of the soil.

Man has, however, shown a wonderful ability to utilize the different food-materials and to produce increased supplies from a limited area when he has been compelled to do so. The Harlemer polders support nearly two and a half persons to the acre, and in portions of China and Japan five or six persons often get their living from this extent of soil. These lands, however, are exceptionally fertile. But even on an average acre of land, where the ordinary farmer would make only five dollars' worth of produce, gardeners can easily make five hundred dollars' worth. For these and many other reasons we cannot be very much alarmed about mere food for the race.

It is a narrow view of agriculture, however, which regards this great art only as a means of providing men with the simplest means of existence. We are interested in the progress of agriculture not only as the means of supplying the food necessary for the increasing peoples of the earth, but as the art which chiefly supports man's advancement along all lines, intellectual, moral, and spiritual, as well as physical. "Man shall not live by bread alone." It is a condition of civilization that man is not satisfied with a mere subsistence, but that his wants increase with his development. The modern man is not satisfied with the simplest food or the plainest raiment, or the barest shelter. He wants attractive and delightful food, because such food promotes health, happiness, and the development of his finer nature. Hence there have been developed the various special branches of agriculture and horticulture and the many arts of milling, manufacture, preparing, and preserving the products of the soil so as to make food-substances tempting and delicious, as well as convenient for use. The American people, for example, owe much of their success as purveyors to the clever methods of preparing food-materials of all kinds, and to their skill and taste in presenting them to the public. It is not enough that quantity alone should be considered, for, in these days, quality plays an increasingly important part in food-production. Hence the arts of producing choice meats, "hygienic milk," cereals of greater food-value, etc., which arts may properly be termed the "higher agriculture;" hence also the arts of pomology, viticulture, etc., with the resultant practical arts of wine-making, canning, and preserving, which may be properly considered as a "higher horticulture." These arts, with the important domestic art of cooking, have all been developed in response to man's demand for more refined and delicious food, a demand which is certain to grow more exacting with the progress of civilization. The same law of progress characterizes our demand for raiment and for shelter. With the development of the esthetic sense and the growth of truer ideas of hygiene and comfort, the demand for more beautiful clothing and more sanitary houses will grow steadily.

But this is not all that can be said about the higher results of the new agriculture. Progress in agriculture contributes largely to the intellectual, moral, and spiritual development of a people, as well as to their physical evolution. Perhaps the most encouraging characteristic of the times is the improvement in farm-life in respect to the means of culture. Formerly the isolation and loneliness of country life was the chief cause of that exodus from country to city which until recently continued to depopulate our rural communities. It is a sad fact that the majority of the inmates of our insane asylums in these states are women, a large per cent of them farmers' wives, sent to the hospitals as a result of melancholy induced by the narrowness and monotony of their lives. But now all these conditions are improving. The consolidated school and free transportation of pupils is fast converting the little "red schoolhouse" into a centre of vital community life. The rural free delivery of mails takes not only the letters of friends, but the daily papers and illustrated magazines, into all the farm-homes; the telephone makes visiting easy for lonesome women; and the traveling library stimulates many to improve their minds, who would otherwise live in stupid ignorance. Many of the features which formerly made farm-life so distasteful and narrowing, even maddening at times, are thus being removed; and many of the advantages, which heretofore could be had only in the city, are being put within the reach of those who spend their lives on the farm.

Every one concedes in a general way that the prosperity of one class diffuses itself throughout the whole community; but good harvests are far more valuable and important to the people than prosperity anywhere else. Agriculture not only provides food and raw material for those engaged in manufacture and commerce, but good harvests increase the purchasing power of the largest and most intelligent body of our citizenship, scattered throughout the whole land. The relation of the farmer to the merchant, the miner, and the manufacturer, is indeed a reciprocal one. Each consumes what the other produces. In the circle of trade, whatever produces a demand at any one point accelerates the amount and velocity of exchange in all directions. Good crops, by supplying the manufacturer, merchant, and miner with food or raw materials, are, the world over, the chief factor in profitable exchange.

But abundant harvests signify even more than this. Every series of exchanges must have a beginning, and the first step in starting the movement of products must be taken by those who supply the elementary and vital wants of the race. The miner will dig no ore, the manufacturer make no machinery, the merchant store no goods, until he knows or thinks he knows that somebody wants these things; but the farmer, being very sure that everybody wants food at all times, is sure to plant and to reap, whether there is an expressed demand for his produce or not. The nature of the demand, it is true, will decide for him which seed he should sow and whether on one or two acres;

but sow he will, as surely as the spring comes; and when he sows, he is almost certain to reap. As nature does more work for the farmer than for any other producer, he finds it easier to turn out an almost regular supply of his products. The sun himself is the commander-in-chief of the agricultural army. The changing seasons order the farmer's plowing, sowing, and reaping, and fundamentally every series of human exchanges starts with the farmer.

Good crops are always and everywhere makers of good times. While this is true for all peoples and all lands, it is particularly true of America, which from natural causes is the greatest agricultural country in the world. In this country agricultural prosperity touches, and for a long time to come will continue to touch, the lives and interests of a larger proportion of the people than in any other land. It causes immediately an advance in the standards of living and a broadening in the scope of the demands of the largest number of intelligent, progressive people; and it produces a home market of such tremendous proportions as to furnish independently of foreign nations a sufficient motive for the development of gigantic manufactures and enormous trade. Further the American farmer is a man of so much intelligence and such large wants that his standards of living increase very rapidly with the improvement of his financial condition. He is liberal to his family, ambitious for his children, and he desires above everything else to raise their standard of living and to increase their advantages in all ways beyond those which he himself enjoyed in his youth.

Another cause of the great economic influence of the American farmer is found in the fact that as a rule he owns his own land. In addition to the profit upon his labors he receives the rent on his land. This not only puts a larger sum at his disposal, but it also creates a motive for additional expenditure for improvements and equipments upon that land. The American farmer, moreover, seldom hoards his money, but promptly expends his surplus for improvements, or else puts it in the bank, where others can use it. He is, all things considered, the wisest and safest investor among us, and his prosperity is therefore the greatest blessing that can possibly come to the nation. Our conclusion is thus that the progress of agriculture is the greatest practical concern of civilized man, and especially of the American.

We have found that the problem of agriculture is to produce more and better supplies for the support of human life under conditions that will enable the farmer and his family, and with them the people of the whole country, to live the happiest and most complete life possible, a life which, as the decades and centuries pass, shall be constantly expanding, strengthening, and growing deeper and richer. The question, then, is "How shall agriculture do this?" What prospect is there that this art shall be able to supply these ever-increasing demands, not merely for food to keep the body alive, but for all the resources needed to support a life growing ever more true and beautiful? What encouragement, then, can we find in recent progress, for believing that this world-old art will improve with the years and the demands of the race?

The improvement of agriculture depends, of course, upon the soil, including location as to latitude, longitude, climate, etc., upon the plants and animals used; but most of all, after these things are provided, upon the farmer and his methods. The most we can do here is to give a few illustrations of the advances made in recent years in improving the soil and increasing its fertility, in developing plants, and in training the farmer himself and improving his methods. We hope in this way to give some idea of what we may expect to accomplish in the future for the advancement of agriculture.

Agriculture, the oldest of the arts, was the very latest to apply the discoveries of science. This is due to two causes. In the first place, agriculture is the most difficult of the arts, and involves, one way and another, directly and indirectly, the application of all the sciences. Secondly, its workers have in the past been less trained in scientific methods than those in other callings. Until recently agriculture has been almost wholly an empirical art and only in very recent times has the farmer received any special training for his profession. Always intensely conservative he has learned new methods very slowly. Many breaches have, however, been made in the wall of empiricism which has surrounded him for centuries and the farmer who formerly derided book-farming has now opened his mind to the lessons of science.

Since the farmer commenced to use the teachings of science, the progress of agriculture has been extremely rapid; and as we may expect that agriculture will make gigantic strides in the next decade, the new agriculture, which is based on science rather than empiricism and which is just now being introduced, is destined to advance all the other industries and give the race a new forward impulse.

This we must believe from the progress already made. Consider, for example, the progress made since the time of Liebig in the study of soils. Liebig based all his proposals for the conservation of fertility and the improvement of the soil upon chemical composition, and his teachings did much to improve our agricultural methods. According to his theory the soil was composed of dead, inert matter, and the question was how to provide the so-called mineral food of plants in sufficient quantity and available form. For fifty years all methods of soil improvement and culture were based upon this idea. The soil was supposed to be devoid of all vitality until the crop appeared, and the chief business of the farmer was to destroy every other form of life. The question of nitrogen-supply had come to be looked upon as lying at the very foundation of agriculture and demanding the most careful consideration because the conditions of life in the civilized quarters of the globe were thought to cause a constant loss of nitrogen. Every collection of animals, brute and human, was destroying the combined nitrogen-supply; every town and city was dissipating enormous quantities of it through its sewers and into the atmosphere. Tons of this valuable element were being burned in explosives, and nitrates enough to grow bread for a whole city were being destroyed in single battles. At one time there were many who, like Sir William Crookes, predicted a nitrogen famine in the soil which in time would lead to a bread famine throughout the world.

One does not have to read far in the agricultural literature of to-day before finding that all these ideas have been entirely changed. The soil is now known to be filled so completely with living things as to entitle it to be considered a vital mass itself, and even those elements in it not endowed with life now have the highest significance as the necessary environment of the living organisms which they help to nourish. We know that there are countless organisms in the soil, rendering many different kinds of service in preparing it to be the home of the plants, and, what is more important, in preparing the food for the plants themselves. Some of these organisms dissolve the mineral matter of the soils, others exert their activity on the organic nitrogen in the humus of the soil; others develop parasitically or symbiotically with growing plants, like the legumes, herding in colonies upon their roots and securing by their vitality, in a way we do not fully understand, the oxidation of the free nitrogen of the atmosphere. Still others have the ability, independently, apparently without the aid of plant vitality, either to secure the oxidation of atmospheric nitrogen or to produce ammonia. Investigations along these lines, which have now led to the systematic distribution of nitrogen-fixing bacteria for inoculating the soil, have, for a time at least, dispelled all dreams of early famines, and have given the world an assurance of a sufficiency of bread for at least an indefinite period. The refined scientific investigations of Nobbe in Germany have now been made practically effective in fixing nitrogen in the soil. Soil or seed can now be inoculated with the nitrogen-fixing bacteria just as dough is inoculated with yeast.

Mention might also be made in this connection of the proposals to combine the nitrogen and oxygen of the atmosphere by the electric spark, as is now being actually attempted at Niagara. Definite reports of results are not yet obtainable, but if this can be done on a large scale, we shall be able to utilize the great water-powers to make this valuable food for plants from the inexhaustible stores of the atmosphere.

Great progress has also been made in this country in the study of the physics of the soil, with the result that vast new areas, like the alkali soils, are being reclaimed; and crops have been found for many other soils which were supposed to be useless. The proper comprehension of the relation of the soil to moisture has expelled many of the empirical methods of culture, and has given us a new conception of the meaning of tillage. The same may be said of the relation of the soil to heat.

The main object in all farming being the production of larger yields and better quality of crops, scientific men have given a large share of their energy in recent years to investigations having these objects directly in view. This work has included the testing of field-crops, fruits, and vegetables, for the purpose of finding those best suited to given regions and conditions; the improvement of methods of culture, the production of improved varieties by selection and breeding, and the better utilization of the product. Burbank's marvelous work in new flowers and fruits, trees and plants of all kinds, has at last received the popular recognition it has long deserved. The possibilities in this direction now appear almost limitless.

The staple crops of the country, such as wheat and maize, or Indian corn, have been the subjects of much investigation, covering every phase of their improvement by selection, breeding, tillage, fertilization, harvesting, curing, preparation, and utilization. The results have been of vast practical value. Those in the cases of wheat and corn will illustrate the progress made.

Not only has it been shown that the quality of wheat for special purposes can be materially changed at will to suit necessary conditions or special wants, but the productivity of races or types of the grain can be fixed by systematic seed-selection. For plants can be bred just like animals. Burbank's wonderful work is so well known now that we need not describe it. At the Minnesota Experiment Station new varieties of wheat have been produced by breeding and selection, which, we are told, will increase the yield in the hard-wheat region of the Northwest by from three to five bushels per acre. Reduced to a practical basis, this means an increase in the wealth of the three states, Minnesota, and North and South Dakota, of from $20,000,000 to $40,000,000 annually. The yield and quality of wheats in that region has already shown a marked improvement as a result of the distribution of seed of two or three improved varieties. As varieties suitable for other sections will undoubtedly be originated in due time, the results that will accrue when these methods have been extended to all the wheat-producing areas of the United States can hardly be imagined. The wheat crop of this country for the year 1902 was 675,000,000 bushels, valued at $425,000,000. The average yield of wheat is only a little over thirteen bushels per acre, considerably smaller than that of England where it is twenty-six, and that of Germany where it is thirty-one. If, by the introduction of these improved varieties and of better methods of tillage, the average yield of this country can be increased no more than two bushels per acre, the total increase for the entire country will be 100,000,000 bushels per year, worth about $100,000,000. This would seem to be entirely practicable. If the excellent prospect of increasing the nitrogen-supply in the soil for cereals does not allay all anxiety regarding starvation, the results in breeding new varieties of wheat and other food-plants should certainly put that fear to sleep for a long time to come.

No less interesting and instructive is the recent work in corn-breeding conducted at the Illinois and Kansas stations. Although corn, which is this year yielding probably two and three-fourths billions of bushels, worth approximately one and a half billions of dollars, heads the list of cereals in value, until the valuable work of these experiment stations was announced there had been no material improvement in the production of this crop in twenty years. The Illinois station has shown that if the methods of selection practiced by it, which are quite feasible and within the reach of every farmer, were followed throughout that single state, the increase in production in one year would amount approximately to $20,000,000.

Methods have also been found for changing the composition of the grain itself to meet special requirements: such as an increased yield of oil or of protein. Since the manufacture of oil from corn has become an industry, the amount of this constituent is a matter of considerable consequence. By selection the oil-content has been doubled in some varieties.

The most important question, however, connected with the improvement of corn is that which relates to its value as a well-balanced food. Its relative deficiency in protein has probably been the chief reason this grain has not been more extensively used as a human food in continental countries. It has, therefore, long been a question how to increase the protein in a grain of corn at the expense of the starch and fats. As the nitrogen, like the other constituents in the grain, varies in the different varieties, the way is thus opened for the control of the variations in this important element. The Illinois and Kansas stations have been engaged for some time upon this problem. By the selection of varieties containing a high percentage of protein, it has been found possible to develop strains containing an increased amount of this desirable substance. The protein-content of some varieties of corn, now apparently well fixed, has been increased fully 2.5 per cent, that is, from about 10 to about 12.50 per cent, which makes corn equal to the average wheat in this respect. In special cases it has been increased to even as much as 17 per cent. Should wheat then fail us, Indian corn will be ready to take its place with an equal amount of protein.

The development of the rice industry in Louisiana and Texas furnishes a good example of the building-up of a new industry by the introduction of a new type of seed and of improved methods of cultivation and harvesting. Rice was one of the earliest introductions into this country and was grown for nearly two hundred years in South Carolina and the adjacent states with little improvement of method. It was thought that these states were the only ones that possessed the requisite irrigable lands. It has recently been discovered, however, that the prairie lands of southern Louisiana and Texas will produce large crops of rice, if provided with the requisite water, which is now obtained from bayous or artesian wells. The water is drained off in time to permit the ground to dry and the crop is then harvested with machinery similar to that used with wheat. As a result of these improved methods, the total rice-production of this country has increased in five years from about 100,000,000 pounds to about 400,000,000 pounds. The two states mentioned produce over 90 per cent of this. As the American people import some 40,000,000 pounds of rice annually, there is still room for the development of this industry. It is estimated that there are available in these two states alone 3,000,000 acres of land suitable for rice-growing. This is perhaps the best single illustration of the introduction of new races of seed and the use of improved methods of cultivation in their production.

I wish next to suggest another place where scientific investigations of a similar character are greatly needed. Cotton-culture needs precisely the same sort of attention from scientific men and expert agriculturists as has been given to wheat, corn, and rice. Considering the immense importance of this crop, it is remarkable that it has not received more systematic study.

A group of states in the southern portion of America, constituting less than one fourth of the total area of the United States, grows from 60 to 70 per cent of the cotton consumed in the world. The total value of the annual crop is exceeded, among the cultivated crops of the United States, only by Indian corn and occasionally by wheat, both of which are grown in almost every state. Since it is fair to assume that all the fibers have been pretty well tested as to their capabilities and uses, we may conclude that cotton, now the preferred fiber, is destined to grow steadily in favor with civilized man, and will continue to be used by him in increasing amounts. We are constantly finding new uses for it, and may safely predict that the demand for cotton will increase rather than diminish. It has been estimated that to meet the world's demand, when its standard of consumption has been raised to that of the civilized nations, will require an annual crop of at least 45,000,000 bales. It is therefore eminently desirable that the Southern States of America should meet this demand. Will they do it?

Present tendencies in the cotton world, at least, seem to answer "No." During the last four years the consumption of cotton seems to be rapidly overtaking the production, with the consequence that many of the mills in the United States, in England, and on the Continent have been running on short time. There are two principal causes which have contributed to this shortage. The most important has been the large increase, amounting now to at least 500,000 bales per annum, in the world's consumption. Of this increase, the greater part was in the Southern States themselves, where the consumption of cotton was doubled within the last ten years. These states are now taking nearly twenty per cent of the cotton produced by them. The second cause of the shortage is the failure of the American cotton-planter to respond to the increased demand, and perhaps a slight falling-off in the yield per acre. In fact there are some reasons to believe that the yield per acre has been slowly but steadily declining for a number of years.

Although in many sections from 500 to 800 pounds of cotton may be obtained by good cultivation, the average yield of cotton in the United States is only about 190 pounds of lint per acre. There is evidently great room for improvement in the methods of cultivation and fertilization, and especially for improvement of the plant itself. Any one who has traveled through the South will acknowledge that the methods of cotton-culture are the poorest and most backward used with any staple crop in our country.

Cotton is limited by climatic conditions to that portion of America south of latitude 37. The essential features of the climate in this section are a long, warm season and a peculiar distribution of the rainfall. Statistics show that the fluctuations in the yield per acre in a given section are less in the case of cotton than in that of almost any other product of the soil. The production of cotton may be due to the greater uniformity of all the climatic conditions obtaining in the cotton-belt, but the chief determining condition as between different sections of our country is the amount of light and heat distributed over the required number of days. For cotton is a sun plant. As a rule a certain amount of sunshine produces, upon a given territory, a certain amount of cotton. The distribution of rainfall is also important, but sunlight is the chief factor The plant requires an abundant supply of moisture during the growing stage, but can stand a good deal of drought after the middle of summer is passed. Now the section of the country providing these conditions measures only about 500,000 square miles, less than one third of the total settled area of the United States. Some 50 per cent of this area is contained in farms, and about 21 per cent is improved; but only about five per cent of the total area, or one tenth of the area in farms and one fourth of the area of the improved lands, is annually cultivated in cotton. If the whole area in farms in this section were cultivated in cotton, it would produce at least 80,000,000 bales. So far, therefore, as soil and climatic conditions are concerned, the Southern States can produce seven or eight times as much cotton as they now do.

But soil and climate are not the only conditions. It requires men and mules to make a cotton crop. It is generally recognized that the labor used in the production of cotton is something over fifty per cent of the total expense of growing the crop. This exceeds the cost of labor in growing corn and wheat, and also in many manufacturing industries. But statistics of population show that there is labor enough available in the South to handle an increase in the cotton crop such as the cotton-belt is capable of producing under favorable conditions. The Negro is well adapted for working in the cotton-fields, and his children are the only successful cotton-pickers known. The great need is that this labor be better trained and organized. Although the supply of mules and horses is inadequate at present for the production of a crop of this size, they might be raised within a few years.

We come thus to the question why the South does not actually produce more cotton to supply the world's increasing demand. It is commonly stated that the low prices which prevailed for a number of years led the planters to diversify their farming and to devote more of their means and energy to the production of general farm-supplies. This is true; but when this has been successfully accomplished, the planters should be in an even better position to produce the crop demanded. Where then is the trouble? Experts seem to agree that the chief difficulties are the impoverishment of the cotton-soils through continued cropping under the renting system, and the running-out of the seed. Observation in the cotton-belt leads us to believe that fully two thirds of the planters use seed taken entirely at random from the public gins, about which they know nothing whatever.

It is safe to estimate that the cotton crop could be doubled on the same acreage by the use of good seed and careful methods of tillage and fertilization. Questions of tillage and fertilization must be left to the farmers chiefly, but the experiment stations should take up the question of improving the seed.

Certain definite things should be kept in mind in the process of cotton-seed development. Among these are an increased yield of fiber and of seed, an increased length of fiber with uniformity, the strength of the fiber, the season of maturity, adaptation to soil and climate, and resistance to diseases. It is probable that cotton having these different qualities will have to be bred to suit the soil and climatic conditions of each section. Here then is a great task, one, however, which offers magnificent rewards. It is firmly believed that the scientist and the cotton-planter will together be fully equal to its solution.

We have sought by these few illustrations to show what science has already contributed to the advancement of agriculture and how it may be expected to do still more for it in the future. No one now doubts that the progress of agriculture in the future depends chiefly upon the discoveries in science and their application to the practical problems of the farmer.

The discoveries of science, however, and the demonstrations of the United States Department of Agriculture through its experiment stations, will be of little value to the American farmer unless he is well enough educated to understand them and skilled enough to apply them. More secondary agricultural schools and schools for the training of horticulturists, dairymen, and other specialists are needed in all our states. The higher agricultural institutions and departments of agriculture in our universities are answering an admirable purpose in training experts and investigators; but so far we have very few secondary agricultural schools. It is believed that the next development will be along this line. Certainly the greatest need of American agriculture is farmers trained to habits of observation and skilled in the application of science to their business. What the new agriculture will do for the advancement of the race when even a majority of farmers have learned its methods confounds the imagination. This greatest of productive industries will lay a new foundation, deep and broad, upon which man will build a new life, growing ever nobler and truer "unto the perfect day."

SOME PRESENT PROBLEMS IN AGRICULTURE

BY LIBERTY HYDE BAILEY

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AGRICULTURE is now in a transitional stage. It is passing from the old to the new. It is pupating. The problems are great, and they all have a forward look.

Most of these problems are incapable of solution quickly. They must ripen and mature. They are many; this paper proposes only to state a few of them that appeal most to me, leaving the discussion of them to others.

The problems of agriculture are of pressing importance, both to agriculture itself and to the public welfare. They are of two kinds: (1) the technical problems of the business, (2) the problems of adjustment to the affairs of our growing civilization.

The problems of adjustment are of the greatest public concern because agriculture is our greatest occupation and is necessary to civilization. Of all occupations, it employs most men, most capital, and is followed in the most places. It probably must always employ from one fifth to one fourth of the people of any self-sustaining nation. There are supernumerary, eleemosynary, and parasitic occupations; but agriculture is basic.

Other occupations have had their day in the public appreciation. All of them have been born out of agriculture. Tubal-Cain was the descendant of Adam. The greatest of public problems are to come with the rise of the agricultural peoples. Just because it is basic, agriculture has been conservative and patient. Fundamental strata are likely to be azoic; but in great world-movements they are also likely to rise permanently to the top.

The farmer is a wealth-producer. Therefore his importance in the body politic is primary. He deals with elemental forces. As a wealth-producer, he will come to have a larger voice in the expenditure and waste of wealth in maintaining armaments of war. All his instincts are of peace.

The public problems of agriculture have been slow to gain recognition. The agricultural questions that we customarily discuss are those of the individual farmer. The burden of our teaching has been that the farmer must be a better farmer. Only in recent years has it come to be fully recognized that agricultural problems are of the greatest national and governmental significance. Consider how recent is the Land Grant Act, the secretaryship of agriculture in the President's cabinet, the Experiment Station Act, the origin of a definite farmers' institute movement, the development at public expense of fertilizer and feed controls and other policing policies, the making of liberal grants of public money for specific agricultural uses.

Governmental fiscal policies have been shaped primarily for other occupations, as, for example, the tariff for protection. This is primarily a manufacturer's policy. It matured with the rise of concentrated manufacturing. One of the stock arguments of the protectionist when addressing farmers is that any policy that aids manufacturing interests must indirectly aid them. I am not here to discuss or to criticise tariff legislation, but it is apparent that such legislation is only secondarily of benefit to agriculture. It has been the history of institutions that special and organized interests receive attention before care is given to the common people and the masses.

We have really not endeavored, as a people, to solve our technical agricultural problems until within the present generation. We have escaped the problems by moving on to the west. Thereby we have fallen into the habit of treating symptoms rather than causes, as the policeman does when he orders an offender to "move on," and leaves the real difficulty for some one else to solve. Even yet, farmers are moving on to find land that is not depleted and regions free of blights and of pests. The real development of agriculture lies in developing the old areas, not in discovering new ones. When virgin land can no longer be had, scientific agriculture will come. An isolated island develops something like a perfected agriculture, as one may see in Bermuda or Jersey. The earth is an island: in time it will be developed.

As agriculture comprises a multitude of different businesses, everywhere touching many sciences and having contact with many public questions, so it is impossible for one person adequately to state even its present and pressing questions. I have been in the habit of inquiring of farmers, students, and colleagues what they consider the agricultural problems to be. Many of the problems that they have stated to me are temporary, local, or incidental. Others are common to many occupations, having to do with the general constitution of society and the general trend of economic events. In this paper I have tried to assemble statements of such questions as appear to me best to illustrate the complex nature of the subject before us. I wish I could give credit to the sources of all the suggestions, but this is impracticable, even though in some cases I have followed very closely the ideas and the language of my informants. I shall be obliged to assume full responsibility for the statements.[1]

The Technical Agricultural Problems

In America the so-called problems of agriculture have been largely those of the mere conquest of land. They are the result of migration and of the phenomenal development of sister industries. They have resulted from a growing, developing country. They have been largely physical, mechanical, transportational, extraneous — the problems of the engineer and inventor rather than of the farmer. The problem has not been to make two blades of grass grow where only one grew before, but how economically to harvest and transport the one blade that has grown almost without effort.

During the past hundred years there has been an area of development on the western border of the country, and this border has been able to compete at an economical advantage with the older area farther east. The price of land has fallen in the East, while it has risen in the West. From 1870 to 1900 we practically doubled our population and doubled our agricultural area. Aside from the geometrical increase in the population, this development has been due largely to a fertile, level, practically treeless prairie. Hitherto the axeman had hewn his way tree by tree. The development of the area west of the Mississippi River is probably the most remarkable in the history of the world. A second cause for this development is the consolidation of railroads into transcontinental lines; and another is the improvement of labor-saving machinery, of which the self-binding harvester is the most conspicuous example, a machine that first attracted wide attention at the Centennial Exposition in 1876.

To this day the American is a cheap-land farmer. A few minutes on the train from a European city brings one into a highly tilled agricultural country. The other day I took an express train from New York City. It was three quarters of an hour before I saw what I could call a farm, and a full hour before I reached a farming country.

As early as one hundred years ago, a distinct movement for the betterment of agriculture had set in. This movement was largely educational. It was an effort to improve the farmer quite as much as to improve the farm. Washington was vitally interested in the problem. He wished to have a central board or clearing-house for agricultural information. The full fruition of his hopes came with the establishment of a secretaryship of agriculture in the President's cabinet, in Benjamin Harrison's administration. In 1799 a concrete proposition for the establishment of an agricultural college in Pennsylvania came to an untimely end. In 1821 instruction was given in agriculture in the lyceum at Gardiner, Maine. In 1824 a school of agriculture was opened at Derby, Connecticut. A number of other similar attempts were made previous to the passage of the Land Grant Act of 1862, but of these only two or three persist. The gist of the whole movement was to adapt education to men's lives. The culmination was the Land Grant Act, the purpose of which is "to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life." So far as agriculture was concerned, the Land Grant Act was somewhat premature. The developing and organizing mechanical and engineering trades were the first to profit by it. Agriculture will now have its turn.

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[1] I am under special obligations to my colleagues, Professors Hunt and Lanman, and to one of my students, Mr. Charles Aronovici.

The tide to the limitless west rose and fell, and we came to a pause. The technical problems of the farmer called for study. His personal difficulties pressed for solution directly on the farm. These problems are of two categories: (1) to remove the special disabilities (insects, fungi, weeds, animal diseases), (2) to augment production (fertilizers, soil studies, tillage, improving plants and animals). Then was born the experiment station (in 1887): the idea is to improve the farm; it is investigational, not educational.

How special the purpose of the Experiment Station Act is may be seen at once from the purposes that it definitely mentions:

"That it shall be the object and duty of said experiment stations to conduct original researches or verify experiments on the physiology of plants and animals; the diseases to which they are severally subject, with the remedies for the same; the chemical composition of useful plants at their different stages of growth; the comparative advantages of rotative cropping as pursued under a varying series of crops; the capacity of new plants or trees for acclimation; the analysis of soils and water; the chemical composition of manures, natural or artificial, with experiments designed to test their comparative effects on crops of different kinds; the adaptation and value of grasses and forage-plants; the composition and digestibility of the different kinds of food for domestic animals; the scientific and economic questions involved in the production of butter and cheese; and such other researches or experiments bearing directly on the agricultural industry of the United States as may in each case be deemed advisable, having due regard to the varying conditions and needs of the respective states or territories."

The experiment stations are holding to these special fields with great faithfulness. In a lot of three hundred and fourteen bulletins that came to my attention bearing the date of 1903, the following rough classification of subjects was made:

Bulletins, 1903

Insects, diseases of plants	63 or 20 %
Feeding and grazing	52
Fertilizers	37
Farm crops	33
Fruits, orchards	28
Dairy (milk and cheese)	23
Diseases of animals	16
Meteorology	15
Garden vegetables	12
Sugar	7
Natural resources, irrigation	7
Poultry	4
Weeds	4
Ornamental plants	4
Seed germination	3
Educational	3
Forestry	2
General advice, bees, exhibitions, plant-breeding, etc.	1
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Some epochs are now passing — as the fertilizer epoch based on agricultural chemistry. The larger question of self-sustaining farm management is now pressing. Three categories of technical farm subjects are just now beginning to demand much thought: (1) problems of feeding to increase efficiency of farm animals; (2) problems of breeding of animals and plants for the same purpose; (3) problems of the business organization of the farm, or development of a farm-plan. We are beginning to apply research to large fundamental questions. The earlier subjects of investigation in the agricultural experiment stations were mostly the smaller and incidental ones. A good many of them were vest-pocket questions. Now the fundamental or backbone crops and products are being investigated in their entirety — the corn crop, the cotton crop, the grass crop, the milk product, the beef product. The experiment stations are originating a kind of constructive investigational method, and the really great questions are ahead of us. Large problems come last.

We are now just coming to the large question of adaptation of special areas to special purposes. In the future one of the problems will be the more perfect adaptation of the kind of farming to soil and climate. As an illustration, the production of domestic animals for meat and for wool has been most extensive on the western border of the developing country for economic reasons, and not because the area is naturally best adapted to this enterprise. The central Mississippi Valley is primarily adapted to the production of cereals and not so well adapted as the North Atlantic States to the production of grass either as pasture or hay. These Atlantic States are particularly adapted to growing all kinds of trees and of grass. In the course of time, therefore, we may expect that the production of live-stock will become more important in the East. Out of this grow some immediate problems. At present, live-stock husbandry in the East can be carried on economically only when large tracts of land can be purchased at low price. It is possible to purchase small tracts of land at comparatively low price, but not possible to purchase large areas. More of the live-stock will be raised on small farms within the more densely populated districts, with comparatively few animals to a place. This will lead to the question of maintaining the improvement in domestic animals. It will mean the gradual substitution of soiling systems for pasturing systems, and this will lead to remoter economic and social changes.

New industries are to be developed. This calls for special governmental recognition. The national Department of Agriculture aids such new enterprises by giving counsel and investigating the special technical difficulties; but is this kind of aid sufficient? If the government helps new manufacturing industries by giving them special privileges, why not aid new agricultural industries by bounties? If a bounty system were to become a recognized public policy (following perhaps the experience with sugar bounties), would it result in undesirable social and economic changes? The money grants to agriculture are only a fair offset to special privileges given to other industries.

The Social and Economic Problems

We are now returning to the farmer, although still holding to the farm. There is a distinct recrudescence of the educational point of view. The new emphasis is to be placed on the man rather than on his crops. The farmer is a citizen as well as a farmer; he is an important factor in public affairs.

The new education must reach the farmer in terms of the whole man — his particular business, his home and its ideals, his relation to good roads, good schools, the church, to social forces, to all that makes up a broad and satisfying country life. We must give attention to the ideals of living as well as to the ideals of farming. The sanitation of the farm-home, the architecture of the buildings (what silent and effective teachers buildings are!), the reading, the character of the farmyard, the questions associated with the bringing-up of children, the social and commercial organizations — these are the kinds of subjects that the rising educational impulse must attack.

All this enforces the economic and social questions relating to agriculture. The greatest problems of American agriculture are not the narrower technical ones, but the relations of the industry to economic and social life in general. Agriculture has not as yet been able to call to its aid in any marked degree those forces and tendencies which have culminated and been of such economic value in the general business world, in the great productive and distributive aggregations. The complete solution of the economic ills of American agriculture may not be in coöperation, and yet in both the productive and distributive phases this is perhaps the most apparent remedy. Coöperation in distribution has made a beginning, but coöperation in production is still almost unknown. Are Kropotkin's ideals attainable?

The problem of the supply of capital in agriculture has never been solved in this country other than in the most expensive way. Capital must return to the land. Two factors enter into the problem: (1) to demonstrate that capital can be made remunerative in farmed land, (2) to insure that land will not bear an unjust burden of taxation.

Closely associated with the economic side is the sociological phase. In the days when all were interested in agriculture, both school and church flourished, but in these later days both have lost their molding influence in the country, though the former shows signs of renewed activity vital to the community.

The specific economic and social questions that even now press for study are so numerous that they cannot be catalogued in an address of this character. Is there still an active exodus from the country? If so, is the movement caused by purely economic conditions, or is it in part the social attractiveness of the city? In other words, does the education of the farmer fit him for the appreciation of the esthetical and philosophical values of his environment? In what relations do the labor-saving devices stand to the rural exodus? Can it in any way be due to super-population of the rural communities? Are the final rewards of labor greater in the city than in the country? Is the arrested development of country church and school in any way responsible?

What are the tendencies as to size of farms? Is the American, starting with small individual ownership, tending towards consolidation into larger units? Is the European, starting with large landlorded ownership, tending towards small individual units? Are the small farms decreasing in number? In what way does the development of the railroads and electric roads affect the size of farm properties? In what way do the labor-saving devices influence the size of farms? Could coöperation of farmers remedy any tendency towards large farms? Or, are larger farm units to be desired?

What can coöperation do for the farmer? Must it be economic, social, political, or to increase production? What are the moral and psychological effects of coöperation? What relation can coöperation have to the isolation of the farmer? To his hygienic conditions? Is it possible or desirable by means of coöperation to save small individual ownership of farms?

Is it true that the country promotes health better than the city? What are the diseases of the country? Are there mental diseases of isolation? Are most of the farmer's diseases due to his work, environment, or poor intellectual preparation to meet the requirements of his condition? What could the state do for the farmer from a hygienic standpoint? What are the relations of farm water-supplies to the prevalence of typhoid fever and other diseases?

How is isolation to be overcome? By a hamlet system? Or by a distributive system of communication — as by better roads, trolley-lines, auto-vehicles, rural mail delivery, telephones, traveling libraries, coöperative reading-courses? Is the social life of the small village as vital and wholesome as that of the separated farm-home?

These are only the merest suggestions of a very few apparent present problems. They are not to be solved by any *a priori* reasoning, nor by using the stock statistics and opinions of economists and sociologists. The field must be newly studied. New data must be collected. New means of attack must be developed. With much painstaking, actual facts in detail must be secured. What is the actual social and economic status of every farmer in a township? a county? a state? Who knows? History must be studied from a new point of view. The very foundation of historical development is public opinion of the common people; and until within the past century the common man was the farmer. Agriculture is the basis of history. The best data of the actual conditions of the people antecedent to the French Revolution are said to be found in Arthur Young's minute description of the agriculture of France. The historian of agriculture is yet to be born.

As an example of the inadequacy of our information on important economic problems, let me cite the most pressing problem just now confronting the American farmer — the question of farm-labor. Farm-labor is scarce; it is dear; it is inefficient; it is unreliable. Yet we read of the armies of the unemployed asking for bread. Why? Who can answer? Who has the data? There seems to be not one authority to whom we can turn. It is apparent that these serious pressing problems — scarcity, expensiveness, inefficiency of farm-labor — are only symptoms of some deep-seated maladjustment.

A large proportion of the labor on farms is done by the farmer himself or his growing family. The inability to find steady employment for laborers is a very difficult problem. Ordinarily, men desire to work all the time and to use their energy to the best advantage.

A farmer's family arrives at the productive age when the parent is between forty-five and sixty. The farm does not offer opportunity for the sons because the father still desires to maintain his activity. The farmer does not take the boy into his business to the same extent that other business-men do. The result is that the sons must find employment elsewhere, and in the nature of the case they most conveniently find employment on salary. By the time the father is sixty-five to seventy years of age and feels the necessity of giving up the farm, the sons are engaged in other lines of effort which it is not practicable for them to leave. The result is that the farm declines with the declining years of the father and on his death is sold or becomes a rented farm. Occasionally a parent solves the difficulty; and herein a distinct public responsibility rests on the individual farmer.

Is the farm-labor difficulty a too low wage-rate? Is farm-labor inefficient merely because it is cheap? If so, how must the farm be made to be able to pay a rate in competition with other labor? Has the tariff contributed to the inequality? Is social poverty of the country districts a cause? Is the lack of continuity or unsteadiness of farm-labor responsible? Has the decrease in the size of the farmer's family been responsible for part of the trouble? And if so, why has his family decreased? Must the farmer of the future raise his own labor? Must machinery still further come to his aid? If so, what effect will this have on systems of agriculture? Will the urbanization of the country tend to establish a regularity of farm-labor? Will cheap railway rates from cities for laborers aid in maintaining the supply of labor for those living on the land, making it possible for the laborers to find work during winter in some neighboring community (it is said to have helped in some parts of Europe)? Can we develop a competent share-working system, in which the owner of the land still retains directive control? And if so, will social stratification result? Must there come a profit-sharing system? Or must the greater number of farmers themselves become employees of men of great executive ability who will amalgamate and syndicate agricultural industries as they have consolidated other industries? Is the agriculture of the future to be a business of fewer and larger economic units? If so, how will this affect the centres of population and the social fabric? Will the lack of farm-labor force us more and more into "nature farming" — the hay and pasturage systems? What, in short, is the farm-labor problem?

The country as well as the city must be made attractive and habitable. It must express and satisfy the highest human ideals, else it will not attract the best men and women. In area and population, the country is the larger part of the national domain: the improving of the ideals of the persons that live therein is one of our greatest public questions. The farmer is the conservative, not the dynamic element of society. We live in a dynamic social age.

The farmer always will be relatively conservative. His business is rooted in the earth. In a thoroughly well-developed agriculture, the farmer does not move his business rapidly from place to place. He remains while others move on. Therefore is it especially necessary that we extend to him all the essential benefits of our civilization. (I hope he will not care for the unessential benefits.) He has the rural free delivery of mails — although this was thought to be impossible a few years ago. Shall he not have a parcels post? Each year the good roads movement, originating in the cities, is extending itself farther into the real country. Trolley-lines are extending countryward; soon they will come actually to serve the farmer's needs. The telephone, as a separate rural enterprise, is extending itself. Extensional educational enterprises are reaching farther and farther into the open farming districts. Coöperation and organization movements are at the same time extending and concreting themselves.

Farming stands for individualism as distinguished from collectivism. Farming enterprises will be more and more consolidated and capitalized, but they can never be syndicated and monopolized to the same extent as many other enterprises. How best to preserve and direct this democratic individualism of the open country is one of the greatest questions now confronting us.

The art impulse will soon take hold of the country, as it has already laid hold on the city. We have lived all these centuries on the assumption that work of art is associated with buildings and "collections." As nature is the source of all our art, so the time is coming when we shall allow nature herself to express her full beauty and power. We shall go to nature oftener than to art galleries. We shall first remove objectionable features from the landscape — features for which man is responsible — such as all untidiness and blemishes, all advertising signs, all unharmonious buildings. Then we shall begin to work out our enlarging aspirations with the natural material before us — make pictures with sward and trees and streams and hills, write our ideals in the sweep of the landscape and the color of the flowers. Our "art" societies still confine themselves to imitation art. The great art societies will be those that give first attention to nature as it is, and to human ideals expressed in nature, not only as it is represented to be in plastic materials and in paints.

Of all the forces that shall revitalize and recrystallize the country, the school is the chief. The schools make the opinions of the nation. The city school has been developed, but the country school has been relatively stationary; yet every farm family is interested in the school. The farmer believes in schooling, just as completely as the city man does; but he may not be convinced that the schools are really touching the problems of life. Persons make more sacrifices for their children than for any other cause. Probably more persons leave the farm to educate their children than for any other cause.

An ideal condition would be the total abolition of rural schools as such. The custom of setting apart towns and villages into special school-districts in order separately to tax the town or village for school purposes has been a misfortune to the rural schools. The whole school-system of any state should be organized on a broad enough basis so that every boy and girl, whatever the occupation of the parents, shall have the opportunity of securing the same, or at least equally efficient, education. The country mill has gone. The old-time country school is a passing institution. A one-teacher school may be as inefficient as a one-man mill. Schools will be consolidated into larger or at least into stronger units. The first pedagogical result will be the differentiation of the work of teachers — perhaps one of these teachers can give special attention to nature-study and country-life subjects.

The school must connect with real life. It will be one of the strong constructive and dynamic influences in our social organization. At present its influence is receptive and passive, rather than creative. The particular subjects that shall be taught are of less importance than the point of view. Many questions of detail are to be discussed, often with much travail; but the final solution must be to allow every subject in which men engage to find its proper pedagogic place in a wider and freer educational system than the world has yet seen, and to place agricultural subjects with the others and not exclusively in institutions by themselves.

Whatever our doubts and misgivings, the American farmer is bound to be educated. He will demand it. Having education and being endowed with a free chance, he will not be a peasant. Some persons have made the serious mistake of confounding peasantry with comparative poverty. Peasanthood is a social stratum. It is a surviving product of social conditions.

If the open country is to be made attractive to the best minds, it must have an attractive literature. There must be a technical literature of the farm, and also a general artistic literature portraying the life and the ideals of the persons in the country. The farm literature of a generation ago was largely wooden and spiritless, or else untrue to actual rural conditions. The new literature is vivid and alive. The new, however, is yet mostly special and technical, with the exception of the growing nature-literature. Artistic literature of the farm and rural affairs is yet scarcely known. Where is the high-class fiction that portrays the farmer as he is, without caricaturing him? Where is the collection of really good farm poems? Who has developed the story interest in the farm? Who has adequately pictured rural institutions? Who has carefully studied the history of the special farm literature that we already have? Who has written the biological evolution progress that attaches to every domestic animal and every cultivated plant? We need short and sharp pictures of the man at his work and the woman in her home — such quick and vivid pictures in words as an artist would stroke on his canvas. There is nobility, genuineness, and majesty in a man at useful work — much more than there is in a prince, or a general, or a society leader, whose rôle it is to pose for the multitude. The man holding the plow, digging a ditch, picking fruit, the woman sweeping or making bread — what stronger pictures of human interest can there be than these? If I could have the choice of the mite that I should contribute to the developing and the nationalizing of agricultural sentiment, I should choose its literature.

WORKS OF REFERENCE FOR THE DEPARTMENT OF TECHNOLOGY

(Prepared through courtesy of Chancellor W. S. Chaplin, Washington University)

CIVIL ENGINEERING

Allen, Railroad Curves and Earthwork.
Baker, Roads and Pavements.
  Masonry Construction.
Baumeister, Sewerage of Cities.
Bovey, Hydraulics.
Burr, Materials in Engineering.
Church, Mechanics of Engineering.
Comstock, Field Astronomy.
Doolittle, Practical Astronomy.
Foster, Electrical Engineer's Pocket Book.
Freitag, Architectural Engineering.
  Fireproofing of Steel Buildings.
Frizzell, Water Power.
Folwell, Water Supply.
  Sewerage.
Gerhard, Sanitary Engineering.
Harcourt, Harbors, Rivers and Canals.
Hayford, Geodetic Astronomy.
Hazen, Filtration of Public Water Supplies.
Johnson, Surveying.
  Framed Structures
  Engineering Contracts and Specifications.
Kent, Mechanical Engineer's Pocket Book.
Lanza, Applied Mechanics and Strength of Materials.
Marsh, Reinforced Concrete.
Mead, Irrigation Institutions.
Merriman, Hydraulics.
Merriman and Jacobi, Roofs and Bridges.
Patton, Foundations.
Rankine, Applied Mechanics.
Raymond, Plane Surveying.
Searles, Field Engineering.
Sedgewick, Sanitary Science.
Thomas and Watts, Improvement of Rivers.
Tilson, Street Pavements.
Trautwine, Civil Engineer's Pocket Book.
Turneaure and Russell, Public Water Supplies.
Waddell, De Pontibus.
Wait, Law of Contracts
  Law of Operations.
Wellington, Economic Theory of Railroad Location.
Wheeler, Sea Coast.
Wilson, Irrigation Engineering.

MECHANICAL ENGINEERING

Transactions of the American Society of Mechanical Engineers.
Proceedings of the Institute of Mechanical Engineers.

ELECTRICAL ENGINEERING

Transactions of the American Institute of Electrical Engineers.
Journal of the (British) Institution of Electrical Engineers.

WORKS OF REFERENCE RELATING TO THE SECTION OF AGRICULTURE

(*Prepared through courtesy of Professor Liberty H. Bailey, Cornell University*)

(The literature related to technical farm operations and to the scientific phases of agricultural production is now very voluminous. It is comprised in a considerable part of books and also in a great number of Experiment Station publications as well as in the current discussions in the agricultural press. In the field of rural economics and rural sociology there is yet very little specific literature. In this direction the following publications may be consulted for their bearing on the general subject.)

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BAILEY, L. H., The Outlook to Nature.
CROOKES, SIR WILLIAM, The Wheat Problem.
DODGE, J. R., Farm and Factory: Aids to Agriculture from Other Industries.
ELLIOTT, J. R., American Farms.
FAIRCHILD, GEO. T., Rural Wealth and Welfare.
GYÖRGY, ANDREW, The State and Agriculture in Hungary.
HAGGARD, H. RIDER, A Farmer's Year, and Rural England.
HUNT, THOS. F., How to Choose a Farm.
KROPOTKIN, P., Fields, Factories and Workshops.
MEAD, ELWOOD, Irrigation Institutions.
MYRICK, HERBERT, How to Coöperate.
PRATT, E. A., The Organization of Agriculture.
SIMONS, A. M., The American Farmer.
TAYLOR, HENRY C., Agricultural Economics.
WALLACE, HENRY, Letters to the Farm Boy.

Ireland, Industrial and Agricultural (Published by Dept. of Agriculture and Technical Education, Dublin).
Vols. x and xi of the Report of the Industrial Commission, Washington, 1901.
Vols. v and vi of the 12th United States Census.
Division of Statistics, U. S. Department of Agriculture.

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Volume I. History of the Congress; The Scientific Plan of the Congress; Introductory Address; Department of Philosophy (6 sections); Department of Mathematics (3 sections).

Volume II. Department of Political and Economic History (6 sections); Department of History of Law (3 sections); Department of History of Religion (5 sections).

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